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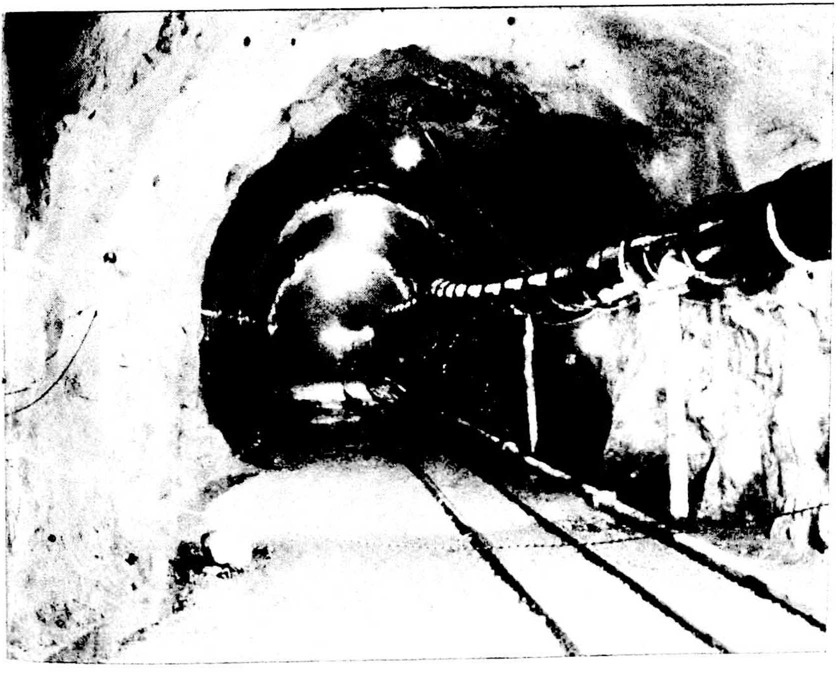
Vol. X JANUARY—MARCH 1956 No. 4



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JOURNAL

OF THE ELECTRICITY DEPARTMENT GOVERNMENT OF MADRAS

VOL. X | JANUARY—MARCH 1956 | No. 4

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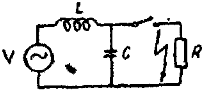
3 MAR 1957

Arc Quenching in Air Blast and Minimum Oil Circuit Breakers

By G. S. Rama Iyer, B.Sc., M.I.E. (Ind.),
Executive Engineer (Electrical and Mechanical)

General theory.

The rupture of an alternating current in a high voltage circuit breaker depends upon the fact, that in the natural passage of the alternating current wave through zero twice per cycle, the space in which the arc burns is converted from the conducting to the non-conducting state so that the voltage, which recurs between the contacts of the breaker after the quenching, can be maintained without restrike. The arc is therefore initially established between the contacts and the arc is got extinguished at a suitable subsequent passage through zero. The conditions required for quenching the arc can be examined more closely with reference to illustrations that indicate the fundamental requirements of the high voltage circuit breaker.



These are (*a*) short circuit interruption (vide Fig. 1).

(*b*) Interrupting high voltage transmission lines on no-load (vide Fig. 2).

(*c*) Switching off power transformers at no-load (vide Fig. 3).

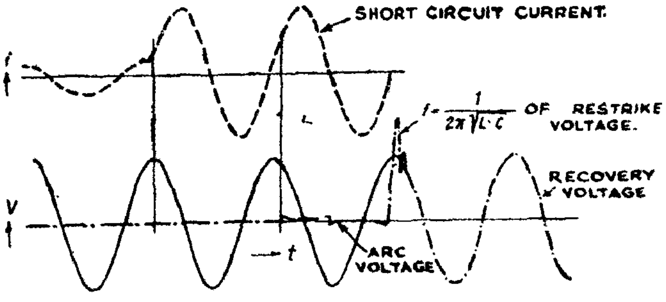


Fig. 1.—Current and voltage curves during interruption of a short circuit in an A. C. circuit.

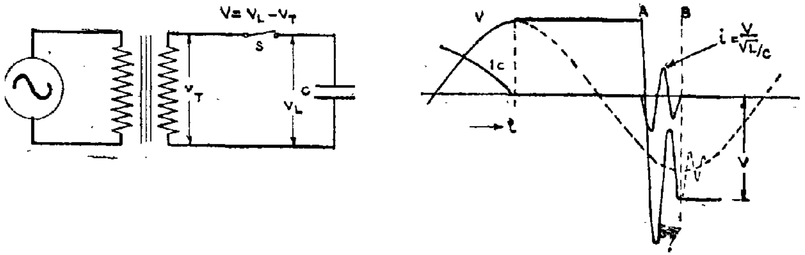


FIG. 2.—Interrupting lines at no-load.

As the last service requirement, the possibility of the " rapid reclosure " should be mentioned.

(*a*) *Short circuit interruption.*—In overhead E.H.T. transmission lines the endeavour to-day is the removal of all short circuits by a short-time interruption of the current. For this purpose all the circuit breakers feeding into the location of the fault are switched out without time delay and switched in again after an interval of no voltage. In the majority of cases the fault is then cleared and the breaker remains definitely closed.

(*b*) *Interrupting lines at no-load.*—As shown in Fig. 2, when switching off lines and cables at no-load, we are dealing with a capacitative circuit in which the charging current I_c **to be interrupted leads** the network voltage by 90°.

When the breaker is opened the capacitative current is interrupted as it passes through zero (i.e.), at the peak voltage of the network. Owing to its capacity, the line remains charged up to the peak network voltage. Further, since the network voltage varies in a sinusoidal manner, the dielectric stress of the break increases and consequently restriking occurs, for example, at the point A in Fig. 2.

The energy stored in the capacity of the conductors discharges back into the network in the form of an oscillation at a high frequency, which is determined by the capacity of the lines and the network reactance. Corresponding to this oscillation there is also a current oscillation which is quenched, if possible, at the point B, where it passes through zero. The line, therefore, remains charged up to the voltage existing at this instant of time. It is possible that this process of transfer of charge is repeated several times, so that the over-voltages can theoretically attain considerable values (vide Fig. 2-A).

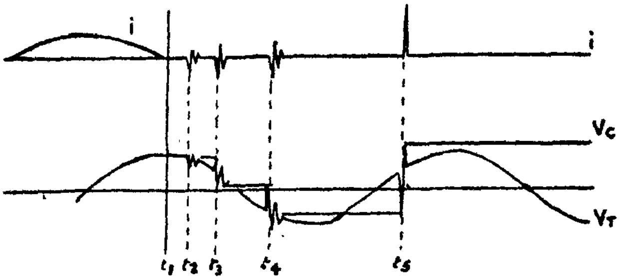
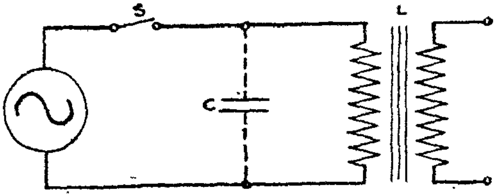


FIG. 2-A.—Current and Voltage curves on switching out lines on no-load. Shows restrikes at t_2, t_3, t_4, and t_5.

In actual field tests in the 220 KV network of France and 380 KV network of Sweden, the over-voltages remained low and attained 2·1 times and 2·4 times phase voltage respectively.

(c) *The switching off of Transformers at no-load.*—Fig. 3 shows the wave form obtained on interrupting a predominantly inductive circuit, wherein the currents are very small in magnitude



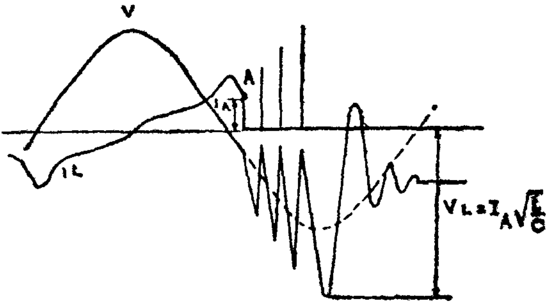


FIG. 3.—The switching off of transformers at no-load—Over voltage due to instability of arc.

and the arc burns at a higher arc voltage, becomes unstable and ruptures easily.

The method by which over-voltages are generated when breaking transformers at no load is briefly explained below. The magnetising current I_L to be interrupted is generally very small being only a fraction of the full load current. Owing to the cooling of the arc that is formed, when the circuit is broken, the current can cease to flow at any instant before its normal passage through zero since the feeble arc discharge becomes unstable; that is, if the energy dissipated in the arc exceeds the energy supplied, the current I in the arc falls to zero shortly before or earlier to its normal passage through zero.

If the inductive current is suddenly interrupted at the point A in Fig. 3 the electro-magnetic energy $\frac{1}{2}LI^2$ stored in the transformer will be converted into electro-static energy $\frac{1}{2}CV^2$. Since the current I_L through the large inductance L cannot suddenly vanish, it discharges into the capacitance of the windings and busbars in parallel with the transformer. That is, the energy oscillates to and fro between the inductance of the transformer and the capacity of the windings, etc. The voltage rises at a rate corresponding to the natural frequency of the network $F = \frac{I}{2\pi\sqrt{L.C.}}$

The higher the natural frequency of the circuit, the steeper is the rise of the restriking voltage and the greater will be the danger of restrike in the path of the break. Fig. 4A shows the rise of the restriking voltage for different frequencies in the first moment after the arc extinction.

The over-voltage peak value of $I_A\sqrt{L/C}$ at the transformer and circuit breaker will occur after the rupture of the arc (I_A is the value of current at the time of the breaking). If the voltage peak reaches the breakdown voltage at the place of break in the circuit breaker, a restrike takes place and the process starts again and repeats many times in quick succession before final extinction (vide Fig. 3A).

It is in fact, the race between the increasing voltage stress versus increasing insulation level.

If the dielectric strength of the break increases too slowly compared to the rise in voltage, restriking takes place and the arc cannot be extinguished until the next passage of the current through zero. But if the dielectric strength of the switch gap increases at least at the same rate as the voltage builds up, then no restriking takes place and the circuit breaking process is completed (Fig. 3), with the network voltage settling down and appearing across the open contacts of the breaker after the few superimposed oscillations have died away. These fundamental requirements must be fulfilled by a really efficient circuit breaker with a short a duration of arcing and without dangerous overvoltage surges during switching operations.

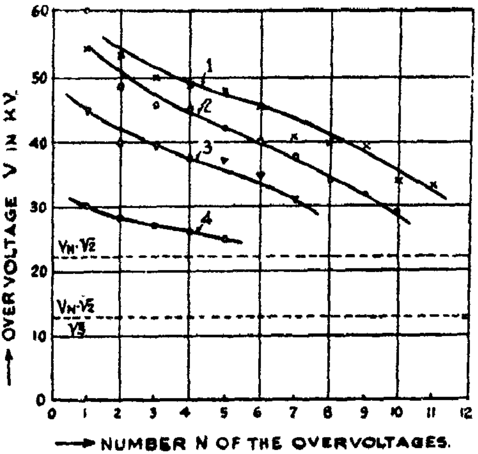


FIG. 3-A—Frequency of the measured overvoltages on breaking a transformer on no-load at a service voltage of 16.5 KV. and 50 c/s. (according to Berger and Jeanrichard).

N = Number of switchings which give over voltages equal to or greater than the peak value.

1, 2 = Triple-pole air-blast circuit-breakers of different makes without resistor steps.

3 = Triple-pole air-blast circut-breaker with multi-step resistor.

4 = Triple-pole oil circuit breaker without resistor steps.

The A. B. C. B. & M. O. C. B.

Many kinds of high tension breakers are built using different quenching methods. As against the conventional bulk oil circuit breakers with its inherent risk of oil fires, a new development in the construction of high tension circuit breakers has been taken up by several manufacturers. This initiative has been rendered possible with a thorough study of the physics of high tension arcing and after systematic experiments in the modern heavy duty high voltage test stations. The design of the special arc quenching chambers, which could cope up with the increasing short circuit stresses of the ever expanding large power systems, has become possible.

Though oil is still continued to be used as quenching fluid by virtue of its high insulating properties, which are of advantage especially for the higher operating voltages, the quantity of oil used in these new types of minimum or poor oil circuit breakers is only a small percentage of the oil quantity required in the bulk oil-tank circuit breakers. Besides this fluid quenching medium type, the other most successful type of high voltage circuit breaker is the one adopting high pressure air-blast as the arc quenching medium. Fig. 4 shows the Brown Boveri A B C B at Erode.

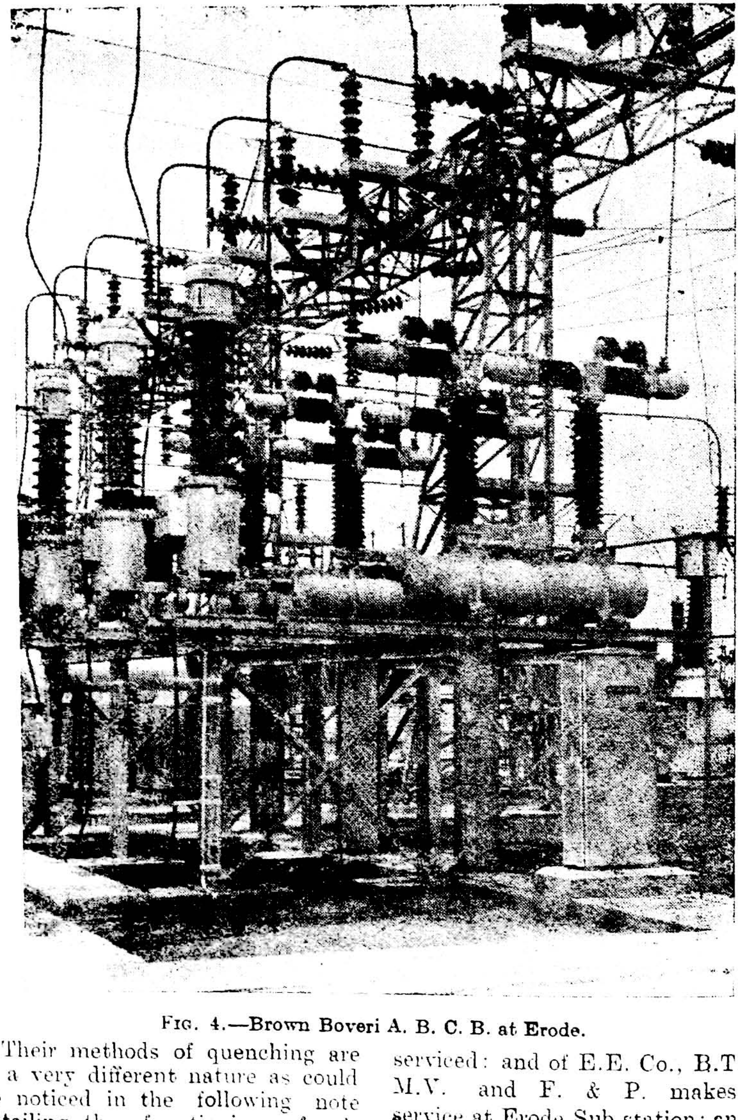


FIG. 4.—**Brown Boveri A. B. C. B. at Erode.**

Their methods of quenching are of a very different nature as could be noticed in the following note detailing the functioning of air blast circuit breakers of A.E.G. and Brown Boveri makes recently serviced: and of E.E. Co., B.T.H., M.V. and F. & P. makes in service at Erode Sub-station; and of minimum oil circuit breakers of ASEA, Oerlikon, Sprecher &

Shuch and Magrini, to be serviced at the Periyar Transformer Yard, Theni, Karuvand-Udumalpet sub-stations. How do the different methods of quenching satisfy the three fundamental requirements of circuit breaker and what are the quenching effects?

To extinguish a high tension arc it is not only necessary to deionize the space between the open contacts, when the current wave passes through zero, that is, to remove the residual arc path, but also '*to aid de-ionization*' by bringing the arc into a favourable formation or shape through cooling and guiding *before* the current has reached zero.

For all quenching methods adopted in the high tension circuit breakers, either a blast of dry air at a pressure of 200 to 300 lb./sq.in. as in the case of air blast circuit breakers: or self-generated pressure gases, as in the case of oil circuit breakers, are used for cooling and de-ionization. While the high pressure air blast is supplied from outside in the case of A.B.C.B., the gases under high pressure are formed by the intense heat of the arc itself, that is, through thermal dissociation of the oil in the case of the minimum oil circuit breaker.

It will therefore be noticed that a clear distinction is made between:—

(1) Quenching methods, where the intensity of the action of the quenching medium *is independent of the current.* The action of the arc extinction medium is *thus separately controlled.* To this group belong the compressed air breakers. The force with which the arc is quenched is governed solely by the pressure of the air injected into the arc chamber. This force is equally strong for large as well as for small currents

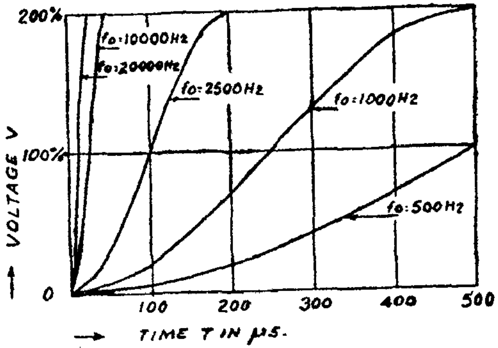


FIG. 4-A.—Curves of the voltage rise at the breakers contacts for different natural frequencies of the short circuit. The average steepness of the voltage rise is $S = 4.10^{-3}$. fo. V max. S in V/us, fo in c/s, V max in K.V.

to be ruptured. These small currents are liable to be ruptured before their natural passage through zero with resultant over voltage due to '*Current chopping*'.

(2) Quenching methods, where the intensity of the action of the quenching medium steadily increases with rising current. The *current* thus *creates its own quenching action*. To this group belong the oil circuit breakers.

This latter group with the arc quenching equipment controlled by the current itself have the advantage of being easily constructed for increasing rupturing capacities subject to the breakers being designed to withstand the intense gas pressure occurring in their arc quenching chambers. The greater the current, the more the oil that is vaporized, higher is the pressure in the quenching chamber and more powerful, the effect on the arc.

The gas pressure can be estimated from the formula

$$P = K I^{1.5} V^{0.5}$$

where I = breaking current
V = recovery voltage
K = constant

For the cooling process two phenomena are responsible:

1. A large volume of oil vapour penetrates into the arc column direct and is there decomposed, the necessary heat for the decomposition being extracted from the arc.

2. In the decomposition of the oil, hydrogen is mainly produced. The arc thus burns in a hydrogen atmosphere and as the heat conductivity and the diffusion constant are several times greater for hydrogen than for other gases a powerful cooling action results therefrom.

Consequent to the above important properties of minimum oil circuit breakers, of cooling of the arc with extraordinary rapidity, its breaking capacity is independent of the natural frequency of the network to which the breaker is connected (vide Fig. 5).

But with this "current-controlled" type of quenching equipment, the obvious disadvantage is that the quenching intensity decreases with decreasing current and thereby can cause such circuit breakers to fail to interrupt small current as with the highly inductive magnetising current during the no load switching off of large power transformers or the capacitative current as in the case of interrupting long transmission lines, unless special additional means in arc quenching chambers are provided.

The length of the arc drawn by the current increases for small inductive currents that are interrupted (vide Fig. 5A). The maxima lying in the range of the small currents (between 10 amps and 100 amps) called the critical current range, are characteristic of all circuit breakers with self-generated quenching medium. In this current range, these circuit breakers quench slowest. The maximum in the critical range is only strongly marked for small power factors. In practice with transformers on no load, the power factor is 0·3 to 0·5, and curve is fairly flat.

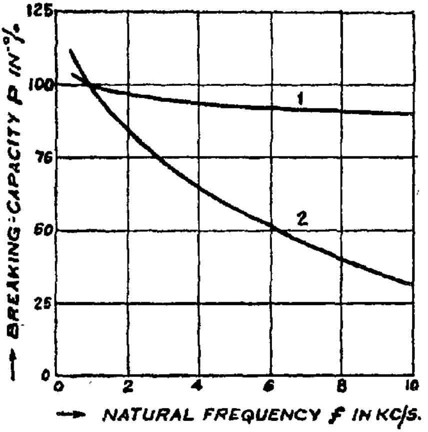


FIG. 5.—Breaking capacity P as a function of the natural frequency of the circuit.
Curve. 1: With a minimum oil circut-breaker.
Curve. 2: with an air-blast circuit breaker in contrast to the air-blast circuit-breaker the capacity with the minimum oil circuit-breaker is practically independent of the natural frequency of the circuit.

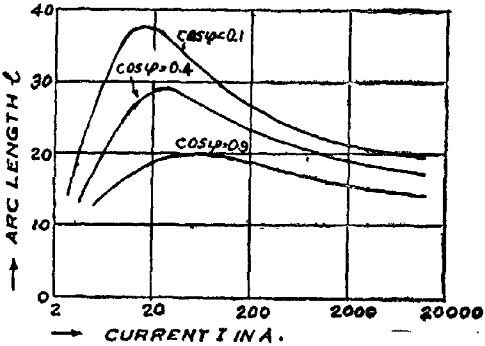


FIG. 5-A.—Arc length *l* as a function of the current I to be broken for different power factors of the circuit. The minimum oil circuit breaker adapts itself flexibly to the current to be quenched.

With smaller currents the arc is quenched in oil circuit breakers through surface cooling alone in the surrounding gas envelope.

ASEA Circuit breaker.

The ASEA design of oil minimum circuit breaker adopts the contraction type extinguishing chamber.

The Fig. 6 (1) to 6 (6) shows the system of operation of the contraction chamber.

The contraction chamber consists of a cylindrical outer casing enclosing the stationary contact of the circuit breaker and a spring loaded differential piston which moves vertically. The moving contact enters the chamber through the orifice in a guiding sleave of insulating material located in the lower part of the differential piston. The piston, fitted with piston rings on the sliding surface, divides the contraction chamber into two compartments that may be regarded as completely sealed and separated from each other. When the circuit breaker opens, communication is

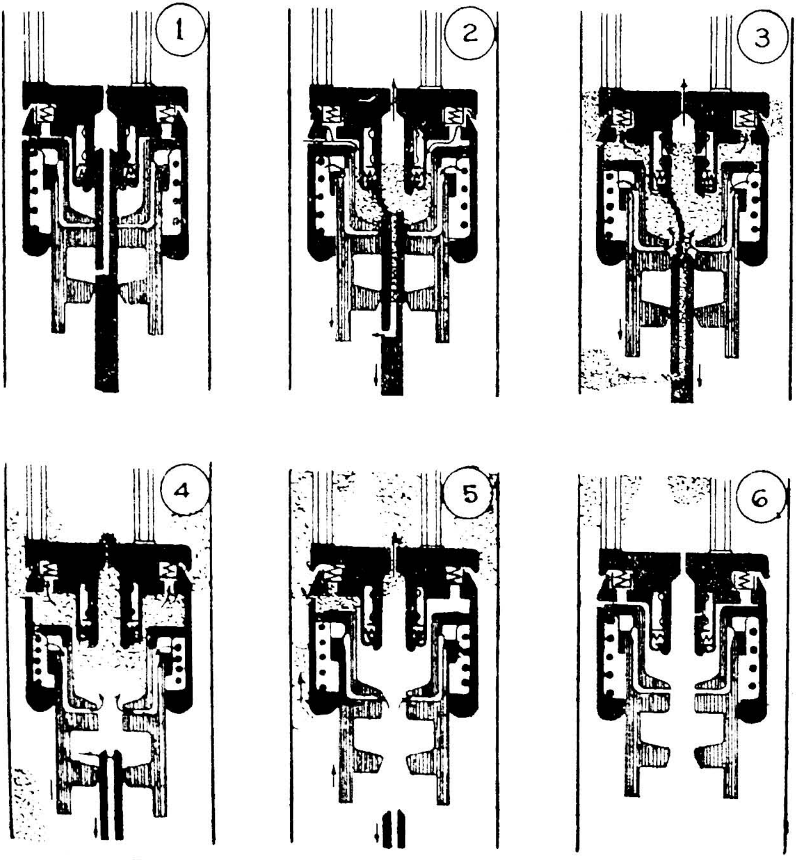


FIG. 6.—System of operation of the contraction chamber.

established between the compartments as the moving contact plug uncovers a slot shaped port in the partition of the piston. This part communicates with the orifice surrounding the moving contact.

The contraction chamber operates, as follows:—

Fig. 6 (1) shows the circuit breaker in the completely closed position. In Fig. 6 (2) the circuit breaker opens. The contacts separate. The arc is struck, with the result that the oil surrounding the contacts in the upper compartment of the chamber is rapidly vapourised. The pressure set up by the oil vapour is transmitted to the lower compartment of the chamber, where it is increased by the action of the differential piston in direct proportion to the ratio of the upper and lower effective piston areas. The oil column in the bore in the moving contact plug is expelled by the pressure of the arc vapours.

Fig. 6 (3) shows, when the part in the partition of the differential piston is uncovered by the moving contact plug, the difference in pressure between the lower and upper compartments of the contraction chamber will cause a rapid flow of oil in the direction of the pressure drop and in passing the port the oil is forced in against the vapour envelope surrounding the arc. At the same time the arc gases escape from the chamber through the bore in the moving contact plug and through several safety valves fitted in the top of the contraction chamber. A powerful vapour stream is thus forced along the path of the arc. When the current wave approaches zero and the generation of heat and vapour subsides, the gas envelope surrounding the arc is compressed by the oil under pressure, hence the term " Contraction Chamber ".

In view of the contraction and the lag in vapour generation due to thermal inertia, a high speed and a high static pressure of the arc gases, flowing along the arc path, will also be maintained during the process of deionization. In this way an extremely rapid deionization of the arc path is obtained.

As shown in Fig. 6 (4), when the interruption is completed, a puncture-proof layer of oil is rapidly injected into the path of the arc. Re-ignition of the arc is thus effectively prevented even if the pressure should decrease rapidly. [vide Fig. 6 (5)]. The difference in pressure between the two compartments of the chamber has been equalised. The differential piston moves upwards under spring action. Fresh oil is streaming into the contraction chamber [vide Fig. 6 (6)]. The circuit breaker is completely open. The differential piston has returned to its initial position, and the contraction chamber is ready for action again.

The Siemen's circuit breaker.

The new type of circuit breaker put on the market by Siemens of Germany is known as " the expansion circuit breaker " containing water or oil as the quenching liquid and is applicable for all ranges of voltage and capacity. With the

quenching fluid of water and glycol mixture known by the patented name of " expansion ", the intense heat of the arc will generate, by thermal dissociation, hydrogen of high thermal conductivity, and therefore forms a suitable quenching media (vide Fig. 7).

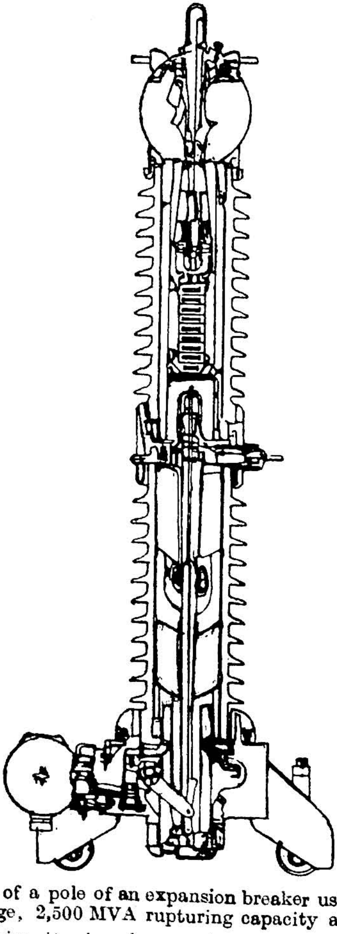
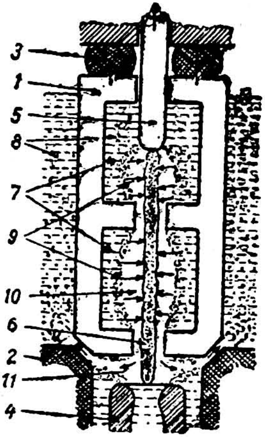


FIG. 7.—Sectional view of a pole of an expansion breaker using oil as quenching fluid, 110 K.V. rated voltage, 2,500 MVA rupturing capacity and 500-A rated current.

The expansion circuit breaker utilizes the expansion method with its intensive continuous cooling of the arc as a means of quenching (vide Fig. 8). Owing to its elastic quenching chamber, there is no critical current range. Equally short quenching times are obtained for all rupturing characteristics (Fig. 9).



1. Quenching chamber.
2. Chamber seating.
3. Elastic ring.
4. Fixed contact.
5. Contact rod.
6. Arc.
7. Fluid-filled compartments.
8. Quenching fluid.
9. Oveheated fluid.
10. Gas envelope.
11. Expanding gas.

FIG. 8.—Quenching by the expansion principle in the elastic chamber.

The chamber has opened at optimum pressure, the gas expands during the reduction of the energy supply as the current wave passes through zero, overheated fluid evaporates explosively, intensive throughout, cooling of the arc path follows through de-ionization and high di-electric strength of the space between the contacts.

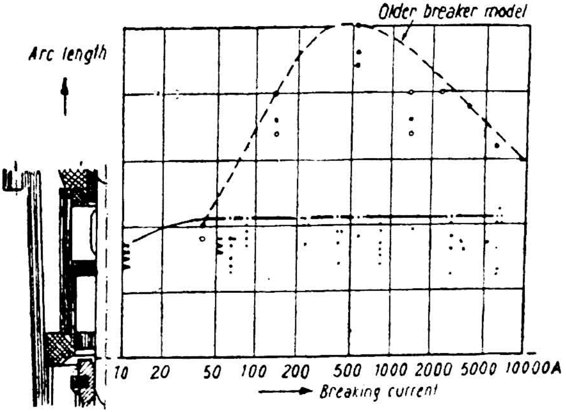


FIG. 9.—Arc length versus breaking current for an expansion circuit breaker with elastic quenching chamber and for an older breaker model with rigid quenching chamber.

The small quenching intensity with small currents prevents excessive switching transients, which would be caused by prematurely, rupturing the arc, before it passes through the zero current point. This is particularly important when disconnecting transformers at no-load as the opening arc is then liable to be unstable and high voltage surges may occur. The problem does not exist with the expansion circuit breakers using expansion as the quenching medium, because of the low conductivity of water (vide Fig. 10).

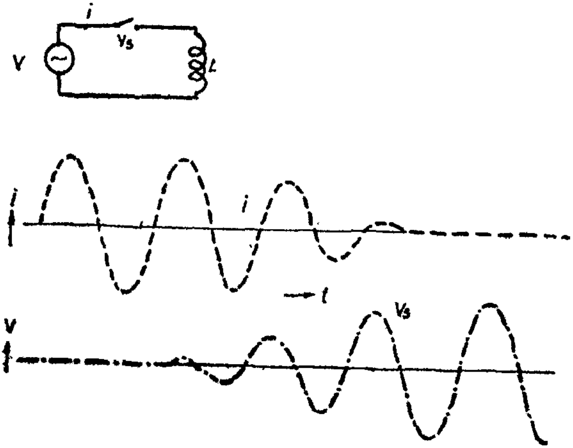


Fig. 10.—Current and voltage cycles during disconnection of a transformer at no-load by an expansion circuit breaker with water as quenching fluid.

In the expansion circuit breakers using oil as a quenching medium, the voltages are limited by the action of the elastic quenching chamber.

Similarly for interrupting capacitative loads, where the quenching intensity is smaller, premature quenching is avoided, or any restriking of the arc occurs at harmlessly low voltages.

Disconnecting open circuit extra high tension transmission lines and cables is particularly difficult, as restriking of the arc can cause a reversal of the charge of the capacitance of the system at increasingly higher voltages. This is controlled by a special device, viz., of automatically connecting resistances into the path of the arc.

The particularly favourable utilization of this property by continuous cooling of the arc in the elastic quenching chamber makes the use of the expansion circuit breaker practically independent of the natural frequency of the system.

The greatest advantage of the fluid circuit breaker with arc controlled action of the quehebing medium is that the necessary stroke of the contact rod (i.e.), the gap

length for arc quenching depends only to a small degree on the voltage and consequently also on the amplitude (overshooting factor) and rate of rise of the recovery voltage (vide Fig. 11).

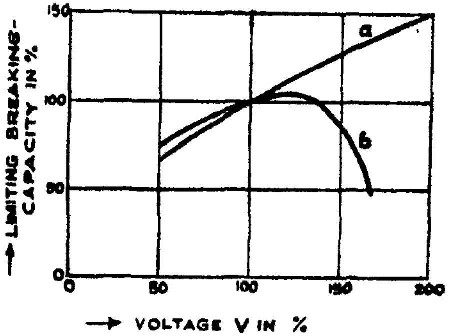


FIG. 11.—Limiting breaking-capacity P of H.V. circuit-breakers as a function of the recovery voltage V.
Curve a : With a minimum oil circuit-breaker.
Curve b : With an air-blast circuit-breaker.
The difference in quenching is the cause of this unequal behaviour of minimum oil and air-blast circuit-breakers.

In contrast, the rupturing capacity attainable with air blast circuit breakers with separately controlled action of the quenching medium, depends very much on the natural frequency of the system (vide Fig. 5).

Further, the intensity of quenching designed for the highest rupturing capacity, is too severe for the interruption of small currents and thus requires particularly careful consideration of no load breaking problems. However, the greater rate of recovery of dielectric strength with small currents is advantageous for switching capacitances, if no switching transients are caused by the instability of the arc through too intensive a quenching action, particularly in inductively earthed systems.

The A.E.G. Circuit breaker.

The details and method of operation of A.E.G.'s preejet Air blast circuit breaker arc described below (vide Fig. 12):—

In the Figure, the three main circuit breaker positions can be seen. They are—

Position "ON".—Contacts closed and pressed together by springs. The switching arms are locked in this position.

Position "Interruption".—The arms are still locked in the "ON" end position; the contact rods are pneumatically pressed into their rear end position, the arc is extinguished and the full isolating strength of the air-gap is obtained.

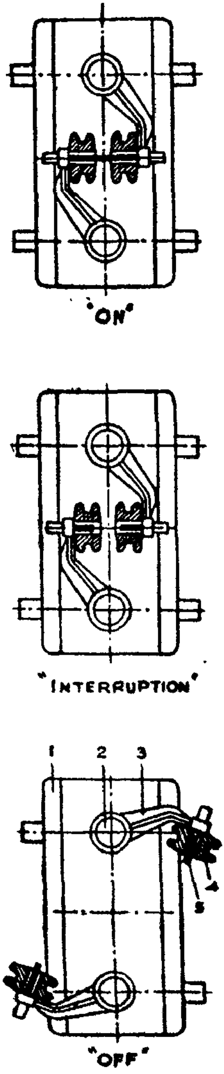


FIG. 12.

Plan view of one pole of 110 K V. breaker of A.E.G. showing opening sequence.

Position " *OFF* ".—The arms and their quenching heads are in the " OFF " end position and held there by springs. The contact-blasting action is completed, and the contact rods return under spring force to the front end position.

This schematic representation shows one of the outstanding features of the free-jet circuit-breaker, that is the distinctly visible break point, which enables a visual check on the condition of the contact rods to be made on the live switch.

The quenching-air pipes inside the post insulators, the switching arms, and the blast nozzles are only under pressure during part of the breaking procedure; in both the " OFF " and the " ON " position of the circuit-breaker they are at atmospheric pressure (this does not apply to all circuit-breaker designs using compressed air as an extinguishing medium).

The quenching head is shown in Fig. 13. The nozzle (11) and the switching insert (8) form the arc-extinguishing or quenching head. Both parts are separately fixed either to the switching arm (1) or to the pillar insulators in the case of a 60-KV circuit-breaker.

The nozzles are made of hard rubber and have an inside profile shaped after the Laval nozzle in order to generate an elongated pressure zone which possesses a high dielectric strength.

1. Air receiver. 2. Rotating post insulator. 3. Switching arm. 4. Quenching head. 5. Contact rod.

Inside the switching inserts slides the hollow contact rod (3) which is fixed to a piston (2). In the "ON" position it is pressed forward and outwards by spring (7) to engage the contact rod of the opposite quenching head. The contact pressure amounts to about 90 to 110 lbs. The current passes from the contact rod to the cylinder wall of the switching insert through special z-shaped ring contacts (10).

During the breaking procedure compressed air flows through the hollow switching arm (1) to the quenching head and occupies the space between the switching insert and the nozzle. Part of the air first escapes through the annular gap between the nozzle and the contact rod into the open, while another portion flows through the vents (9) into the cylinder (4) and propels the piston (2) carrying the contact rod (3) backwards against the pressure of the spring. Before the end position is reached, the movement of the piston is damped by the air cushion in the damping chamber (5). Finally the cup springs (6) prevent the piston from forcibly coming to rest against the back stop. This motion as described takes place within about 2 half-waves (20 ms.).

The return of the contact rod to its "ON" position is effected by the spring (7) and begins, as soon as the pressure within the jet has dropped to about 28 p.s.i., that is, shortly after the closing of the blast-air control valve.

The arc formed on the separation of the contacts is at first subjected to a weak axial blast. The full quenching effect is obtained only after a complete opening of the nozzle-bore by the contact rod. In the end position, part of the quenching air flows through the hollow bolt and expels the metal vapours generated at the roofs of the arc, through the exhaust silencer at the rear of the extinguishing head.

Brown Boveri circuit breaker.

Fig. 14 is a diagram of the DCF type Brown Boveri Air Blast Circuit breaker in "ON" position, the extinction chambers 1a containing no compressed air. The breaker opens when compressed air is admitted to the extinction chambers from main valve 1b through the hollow insulators 30. The moving contact 41 (contact nozzle) opens through the distance h (the extinction stroke), is cushioned off by pneumatic buffer 46 and comes to rest until the arc produced between fixed contact 40 and moving contact 41 is extinguished by the cooling and deionising effect of the air blast at the first current zero. The time, the moving contact remains in the extinction position, is a function of the pressure rise in chamber 34, into which air flows from duct 35 through bore 45, hollow piston rod 37, and hole 33. It is approximately 0·05 second, whereupon the moving contact opens out to the isolating distance H, closing the exhaust valve 42 and sealing the chamber. The air blast is thereby stopped, but the chamber, with contacts open, remains under pressure, the compressed air forming the ideal, invariable insulating medium between the two contacts,

Type DCVF circuit breaker, shown diagramatically in Fig. 15, incorporates resistors 95 including contact device, connecting in parallel with the main contacts. In a breaking operation compressed air is also admitted to the piston 101 of auxiliary contact 100, which closes the resistor circuit already at a pressure of approximately one kg/sq. cm. With rising pressure (approximately 5 kg/sq. cm.), accurately timed, the main contact 41 opens and the interruption of the main circuit is effected. The resistors are at this moment connected in parallel, increasing the rupturing capacity, and in special cases limiting the excess voltages. Apertured diaphragm 99 takes care that auxiliary contact 100 interrupts the resistor circuit approximately 0·05 second after the main contact has opened. Compression spring 98 returns the auxiliary contact to its original open position. The resistor arranged in parallel with the main contacts 40 and 41 is only connected during the breaking process. Resistor and associated auxiliary contacts take no part in the closing operation, excepting the rapid evacuation of chamber 97

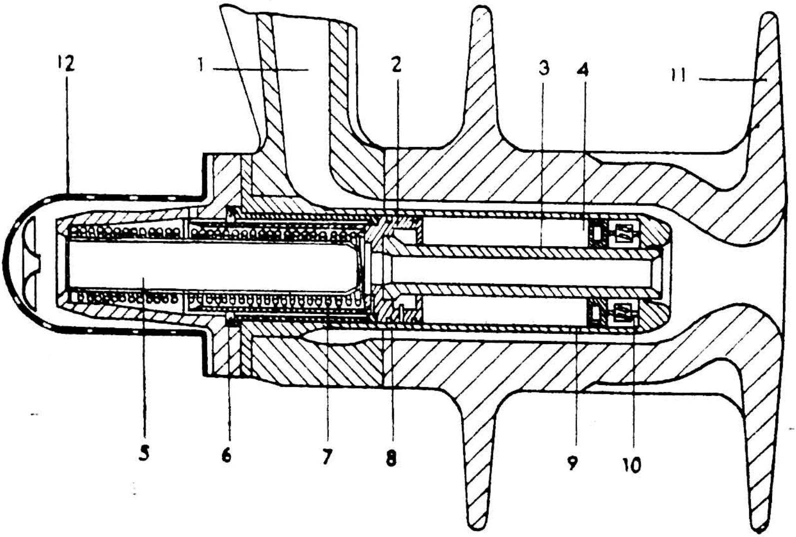


FIG. 13.—Section through quenching headof a 110 KV. free-jet circuit-breaker of A.E.G. in "off" position.

1. Switching arm.
2. Piston (annular).
3. Contact rod.
4. Cylinder.
5. Damping chamber.
6. Cup spring.
7. Helical spring.
8. Switching insert.
9. Vent.
10. Annular contact.
11. Nozzle.
12. Exhaust silencer.

by means of valve 99, which also assumes the delaying function of an apertured diaphragm.

To close the circuit breaker, extinction chamber 1a as well as chambers 38 and 45 are evacuated through main valve 1b. The air locked up in chamber 35 impinges on piston 48 and in unison with the contact compression spring 31 closes the moving contact 41. The breaker is in " On ".

Conclusion.

It is seen that the two types of quenching methods do not equally satisfy all the three basic requirements of high tension circuit breaking and to fulfil the demands of the Power System, use of auxiliary means or some sort of compromise is resorted to in the various designs.

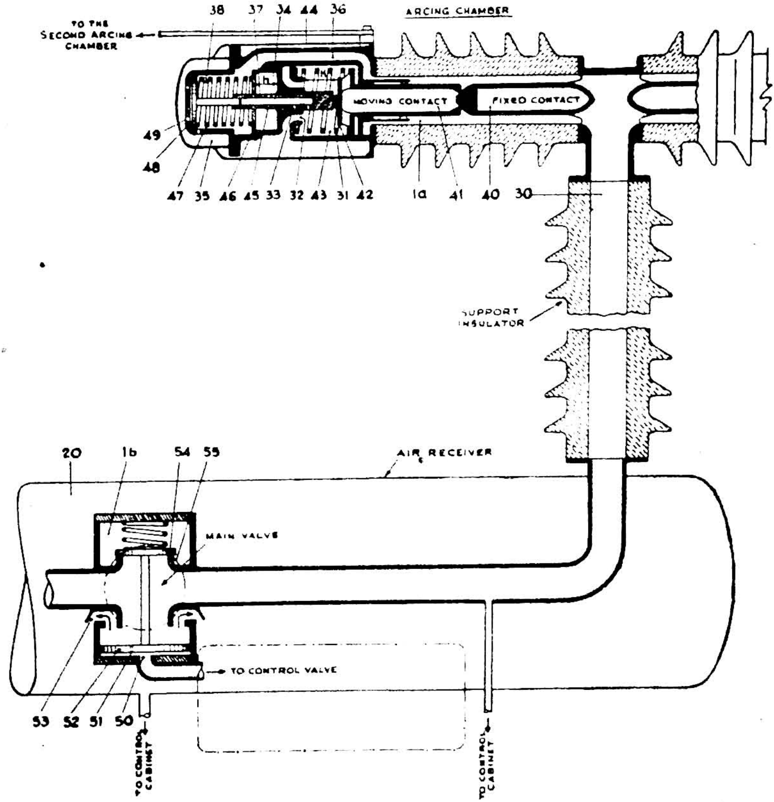


FIG. 14.—Arcing chamber of Brown Boveri A.B.C.B.

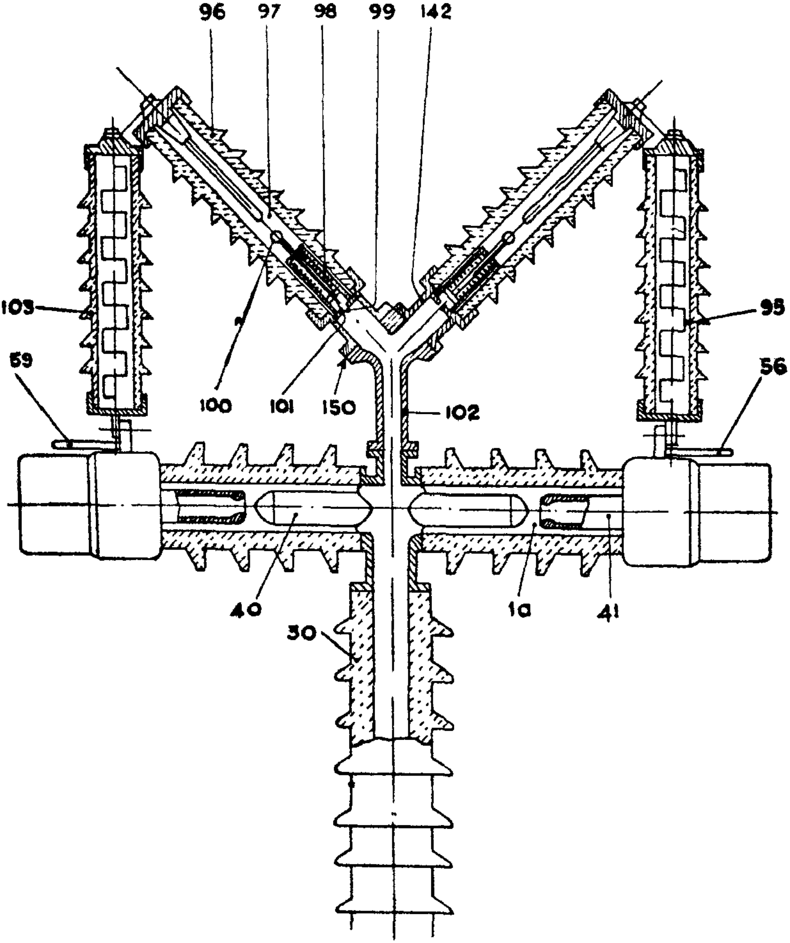


FIG. 15.—Brown Boveri A.B.C.B. with shunt arc resistors.

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Rectification of the Hitachi Turbo Set at Samayanallur

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I. *Introduction.*—The 10 M.W. turbo alternator set supplied by Messrs. Hitachi, Limited, of Japan was installed at Samayanallur Power House and first commissioned on 12th April 1953. The machine has been giving satisfactory performance for over two years. Being a seasonal station the set had to be shut down for varying periods during the irrigation season depending upon the hydro storages and the grid consumption. The suppliers have stipulated that the alternator should be dried out every time before putting into commission, should the idle period exceed seven days at one time.

During one such operation in July 1955 the machine unfortunately broke down under conditions, detailed below.

The set was started on 22nd July 1955 and after completing the drying out operations, the insulation readings of the stator windings were being recorded, for decreasing stator temperature, after switching off excitation. At about 11-45 hours on 24th July 1955 it was noticed by the operator on duty, that there was a failure of oil supply to the six bearings of the machine, and he immediately shut down the turbine. The machine, which normally takes about thirty minutes to decelerate and come to rattling noise in a matter of two or rest abruptly slowed down with a three minutes. The accident was as unexpected as it was sudden.

White fumes were noticed to issue out from all the bearings, as the machine came to rest quickly.

On examination it was found that due to the failure of oil supply, the bearings got instantly seized and the turning (barring gear) operated by a three horse power electric motor could not keep the shaft moving.

II. *Details of damages caused.*—On detailed examination after the breakdown, the following were found damaged:—

(*a*) *On the turbine.*—(1) The bearings of the turbine including the Michell thrust block and the oil throw off plates.

(2) The H.P. and L.P. labyrinth packings.

(3) All the twelve diaphragm packings.

The Turbine rotor shaft was bent seven hundredths of a millimeter, towards coupling end.

(*b*) *On the alternator.*—(1) Both the bearings with the oil throw off plates.

(2) Air sealing rings of the alternator and shields.

(c) *On the exciter.*—(1) Both the bearings of the exciter (the extent of damage on the exciter out board bearing was found comparatively less).

(2) Scouring of the main exciter commutator by the brush holder assembly caused by sinking shaft.

The photographs indicating damages caused to the bearings and air sealing rings are furnished for clarity. (Vide Photos 1, 2 and 3.)

As the machine was covered by a five-year guarantee by the suppliers, the fact of this unfortunate breakdown was cabled to the supplies at Japan and the work of rectification was taken up from 31st August 1955, on the arrival of the service engineers at site.

There were adequate and essential spares readily available at site. Such of the items, which were not available, and had necessarily to be procured by the suppliers were also intimated in time, with the result, that the rectification was planned without appreciable hold up once the work was started.

III. *Rectification.*—The turbine shaft was uncoupled and lifted out and the spare new bearings were fitted up in their housing and the bedding clearances were adjusted. The rotor was placed in position on the bearings and checked for deflection by taking clock gauge readings at different sections of the rotor.

It was noticed that the turbine rotor indicated a deflection of seven-hundredths of a millimeter towards the coupling end, which was considered beyond the permissible limits as per Japenese standards. According to them any deflection exceeding 2·5 hundredths of a millimeter required rectification. Consequently this deflection of the shaft assumed major importance and as per expert advice of Hitachi Engineers this deflection was straightened locally by hammering near the point of deflection.

The details of this rectification are elaborated below:—

The turbine rotor was mounted on two concrete supports with the concave surface of the deflected portion of the shaft (as determined from the dial gauge readings) upwards.

At the point of curvature, where the shaft bends upwards, a screw jack was placed exactly below in position and it was so adjusted as not to strain the shaft between the points of supports, and at the same time just not to allow the shaft to bend downwards even slightly under impacts.

The treatment given to set right this bend consisted in giving repeated hammer blows at the point of deflection on the concave side of the shaft without any heat treatment with a support below, so that the stresses on the skin of the shaft could be relieved resulting in the shaft regaining its original straightness gradually.

A twelve-pound hammer was used in conjunction with a blunt chisel-pointed brass rod to transmit the blow at the desired point without injuring the surface of the shaft. The jumping of the brass rod under the action of hammer blows due to the natural springness of the rotor shaft was partly arrest-

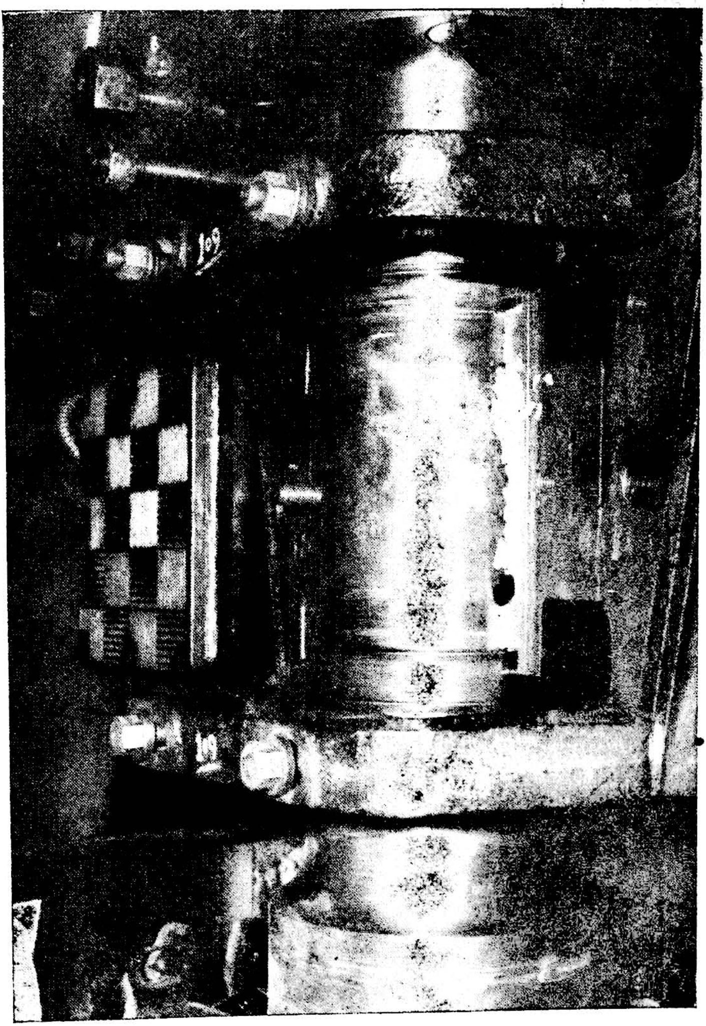


PHOTO 1.—Showing damage caused to bearing 3.

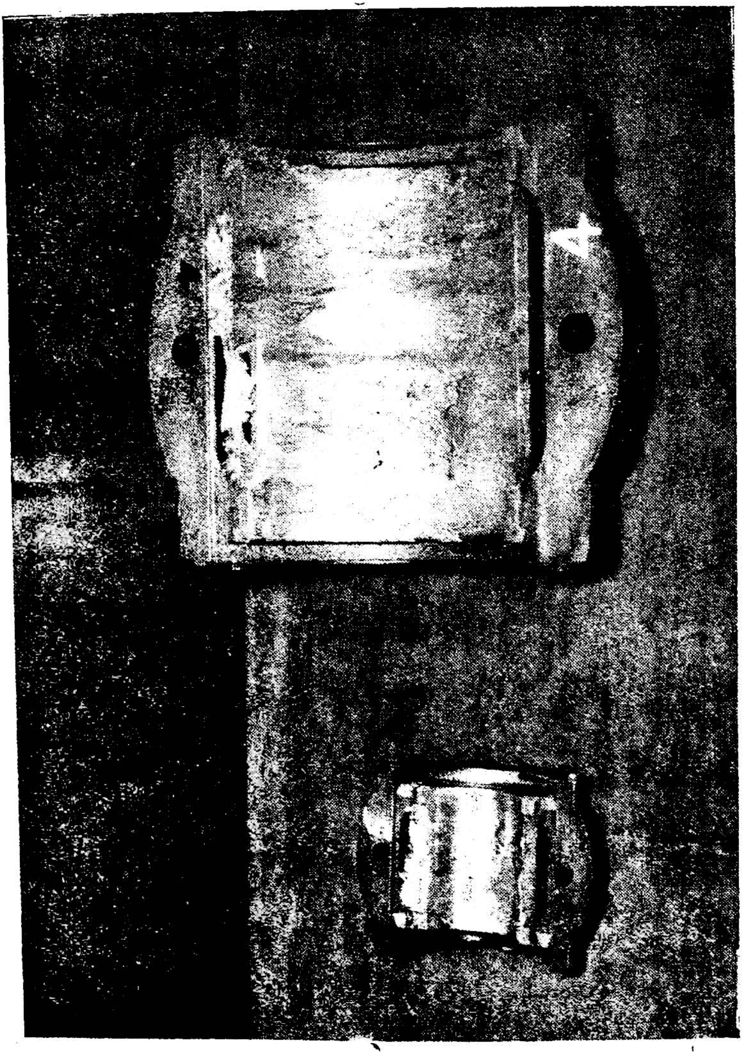


PHOTO 2. —Showing damage caused to bearings 4 and 5 (top halves)

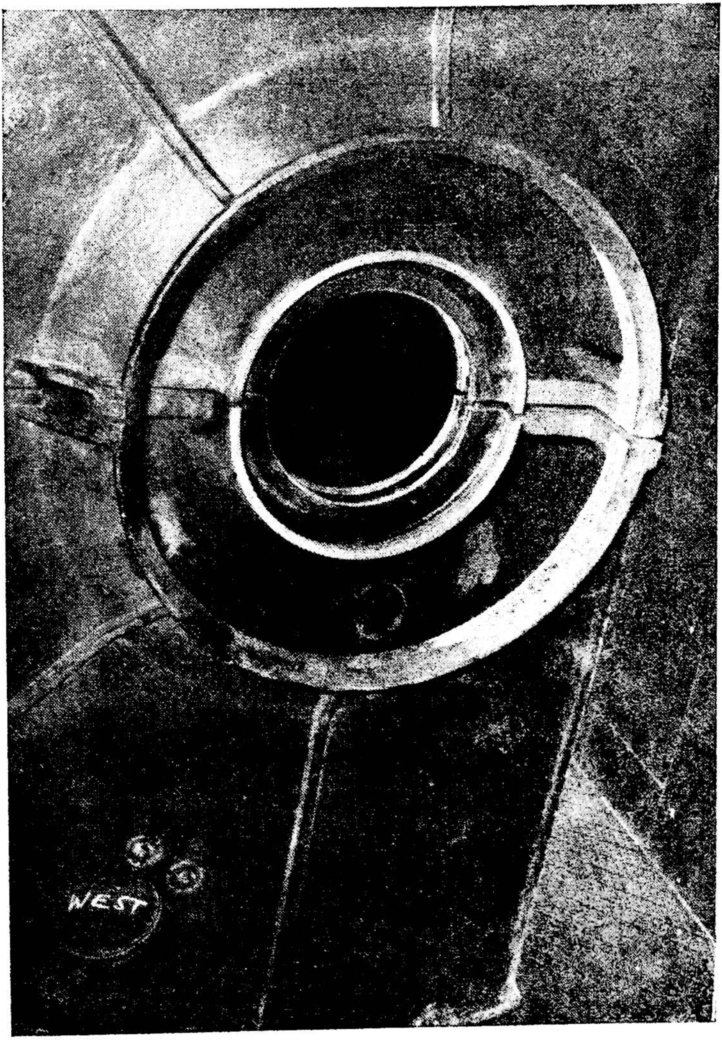


PHOTO 3. —Showing damage to the air sealing rings of the alternator end shields.

ed by tying the brass rod with rubber cords so that the rubber cords would take up this shock to some extent.

The whole arrangement is clearly indicated in the photograph appended (Photo No. 4).

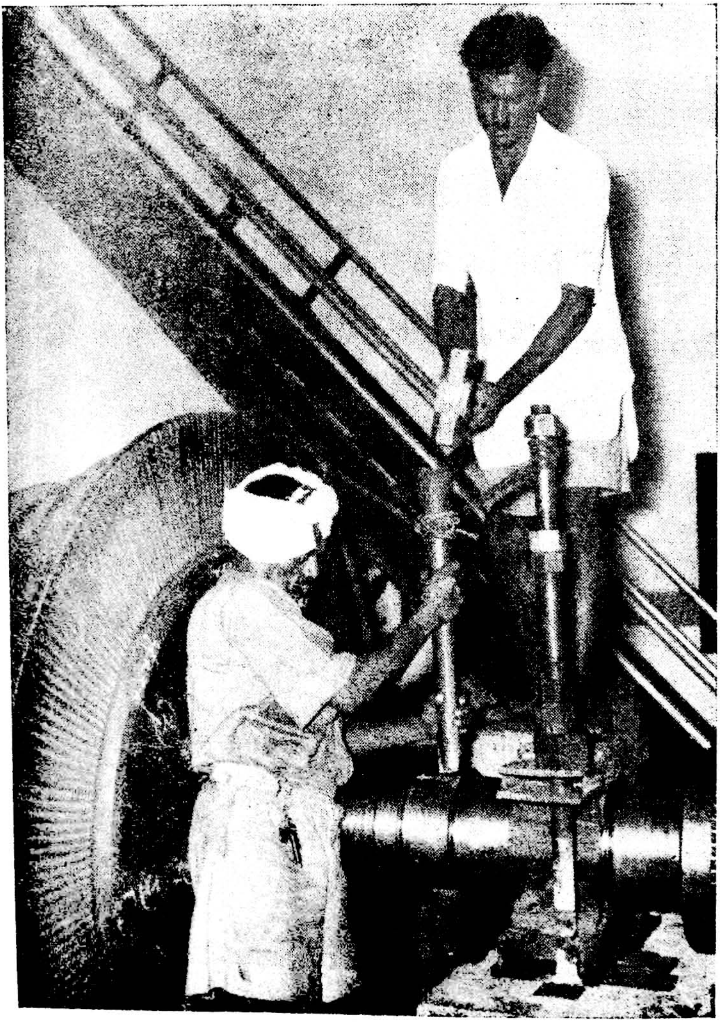


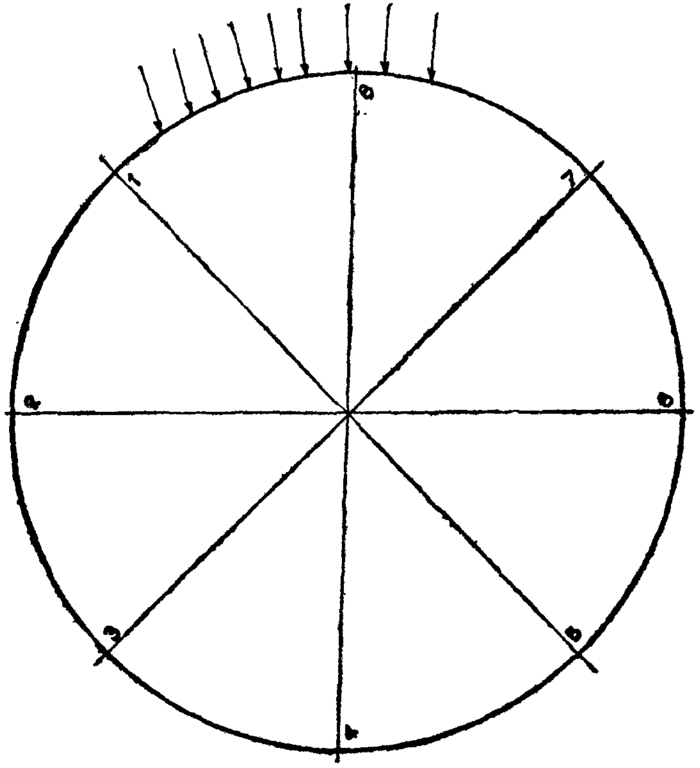
PHOTO 4.—Showing straightening of the shaft.

After every five hundred hammer blows dial gauge readings were taken and the extent of improvement of deflection was checked.

This treatment was applied over the deflected portion on the periphery of the shaft, which roughly ranged to about one-eighth of the periphery of the shaft as shown in Sketch No. 1.

A total of 16,500 hammer blows in all were administered to bring down the deflection within two hundredths of a millimeter, which is well within the tolerance prescribed.

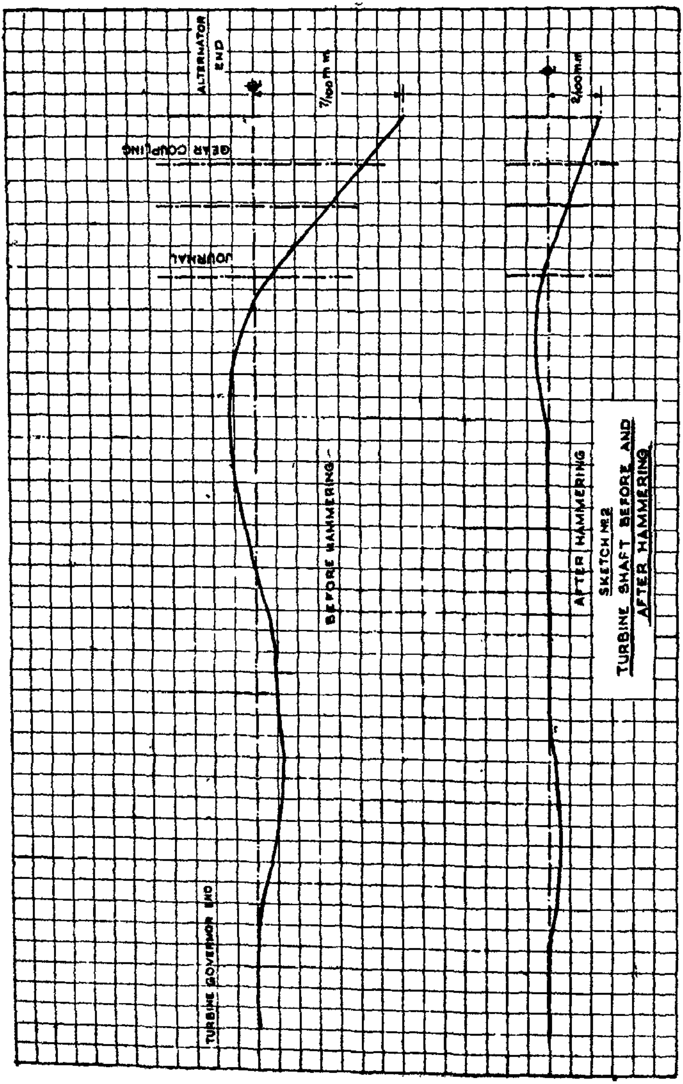
This work of straightening the shaft took about four days. At every stage extreme care was taken



SKETCH 1.—Showing periphery of the shaft where hammer blows were administered.

to administer the blows at the correct area with precision to achieve the desired results.

The disposition of the shaft before and after rectification is indicated in Sketch No. 2. Also the details



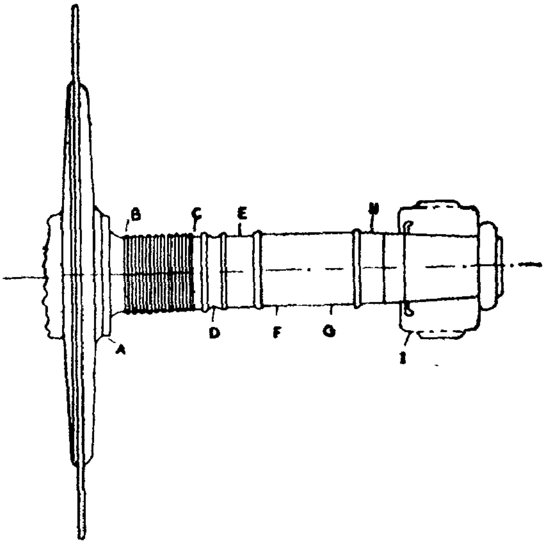
SKETCH 2.—Turbine shaft before and after hammering.

of deflection of the bent portion of the shaft from the end of the last stage of the steam rotor, up to the flexible coupling gear end as recorded by the clock gauge are tabulated.

	A	B	C	D	E	F	G	H	I
Extent of deflection before treatment in hundredth of millimeter.	2·25	2·25	0·5	1·75	1·75	1·25	1·5	3·5	5·5
Extent after treatment in hundredth of millimeter.	0	0·25	0·5	0	1	0·5	1·25	1·75	2

The locations on the shaft where the dial gauge readings were taken are indicated in Sketch No. 3.

The theory involved in straightening turbine shafts which have suffered deflection of a few hundredths of a millimeter over a short length is briefly explained below. It is common knowledge that when a beam or a shaft is bent the concave side will be in compression and the convex in tension. To straighten such shafts it becomes imperative to relieve these stresses at such section so that they may regain original straightness. This can be achieved by varying methods. Heat treatment at the affected



SKETCH 3.—Showing locations on shaft where gauge readings were taken.

section is one such known method. The method employed at Samayanallur, viz., administration of repeated and sudden hammer blows at the concave surface of deflection (duly supported below) resulted in achieving the same aim as obtainable under the heat treatment. The compressive stresses along the surface of the shaft at the point of deflection are partly relieved or neutralized by tensible stresses brought about by hammering. To that extent the deflection is reduced. This method had the additional advantage, that the entire operation is controlled and also could be accomplished locally without involving any special equipment therefor. Luckily there was no need to despatch the rotor to the works and the consequent delay and expense were avoided.

The set of bearings for the turbine, along with the oil guards, the Michell thrust pads with segmental ring, were all renewed. New diaphragm packing rings were fitted and their clearances to shaft were adjusted and they ranged from 0·38 millimeter to 0·5 millimeter. Fresh H.P. and L.P. labyrinth packings were fitted up and clearances checked. Alternator bearings along with the oil throw off plates and guards were renewed. The alternator shaft end shield air-sealing rings, were also renewed and clearances adjusted. The exciter commutator surfaces were skimmed to a depth of 0·7 millimeter and both the bearings with the oil throw-off plates were renewed. The exciters both main and pilot were overhauled and assembled. The turbine and alternator shafts were then aligned by suitably adjusting the thickness of the alternator bearing pedestal insulation and by introduction of appropriate liners at the turbine bearing housing at coupling end. The alignment was done up to an accuracy of two-hundredths of a millimeter. Simultaneously, overhaul of the auxiliaries of the machine such as governor assembly, servomotor, main and auxiliary oil pumps, oil cooler, oil strainer connected piping, air cooler, etc., were all attended. After a thorough inspection and cleaning of the machine, the set was boxed up and got ready for trial run.

IV. *Trial runs.*—The complete oil system was flushed with flushing oil for twenty-four hours. The bearings and oil reservoir were cleaned and the same were filled with D.T.E. heavy medium oil after flushing. The trial runs were started on 26th October 1955, within seven weeks from commencement of rectification. As the bearing temperatures rose initially high beyond 150° F, the bearing metal was scraped and clearance adjusted to ensure better bedding. Finally after two trial runs the bearing temperatures came down to 130° F

and continued steady. The satisfactory functioning of the emergency governor was also verified. After the usual drying out of the alternator, performance tests of the machine on load up to full rating were conducted for a period of one week.

The lateral, axial and vertical vibrations of the set were taken at each of the six bearings, using an optical vibrometer, when the set was loaded to its full rating of 10 M.W. The maximum vibration recorded are tabulated below and are within permissible limits:—

		Bearing. (1)	Bearing. (2)	Bearing. (3)	Bearing. (4)	Bearing. (5)	Bearing (6)
Lateral	Reading	2	2	5·5	6	2	6
	Deflection m.m. ..	·007	·007	·030	·034	·007	·034
Axial	Reading	2·5	6	6	5·5	4·5	3
	Deflection m.m. ..	·010	·034	·034	·030	·024	·014
Vertical	Reading	2	4	7	1	3	3·5
	Deflection m.m. ..	·007	·020	0·041	0	·014	·017

NOTE.—The vibration is nil when reading is 1. Constant for getting correct vibration is (Reading —1) × ·0068 m.m. for the optical vibrometer used for test.

V. *Conclusion.*—The performance of the set after the rectification has been found to be satisfactory and the set has been in service almost continuously from December 1955, affording the much-needed relief to the Grid.

It is fortunate that the set was recommissioned satisfactorily within a short period after the accident, thanks to the efforts of the Hitachi Service Engineers, who were assisted by the local Departmental staff.

Earth Electrodes and Measurement of Earth Resistance

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1. *Introduction.*—The earthing of the metal parts of electrical machinery and equipment is necessary for their protection and for the protection of persons working on them or coming in contact with them. The earthing of the neutral of transmission and distribution systems is also done for the operation of protective gear, reduction of fault currents, etc. It is therefore essential to provide a good connection between the part of the installation or machinery to be earthed and the general mass of earth around it.

This article briefly deals with the earth electrodes employed for the earthing of installations and machinery and with the measurement of earth resistance.

2. *Earth electrodes—(a) Methods of earthing.*—The object, to be earthed, is generally connected to the general mass of earth through an earth lead connected to one or more earth electrodes, which are buried or driven in the ground. Such electrodes may consist of—

(i) Metal pipes, usually G.I.,

(ii) Metal plates, usually cast iron,

(iii) Rolls of wire,

or any *other* means of making contact with the mass of earth. Metal water mains are sometimes used for this purpose as they have a large surface contact with the earth.

The resistance of an " earth " is made up of—

(i) The resistance of the earth electrode itself.

(ii) The contact resistance between the electrode and earth.

(iii) The resistance of the general mass of earth surrounding it.

If the overall resistance of the " earth " is to be as low as possible, it will be necessary to keep the above three individual resistances as low as possible.

The resistance of the earth electrode is kept low by using electrodes of sufficient size.

The contact resistance between the electrode and the general mass of earth surrounding it is always difficult to keep low. Due to deterioration of the electrode and to cell action, which results in a film of gas forming around the surface of the electrode, the contact resistance is greatly increased. The

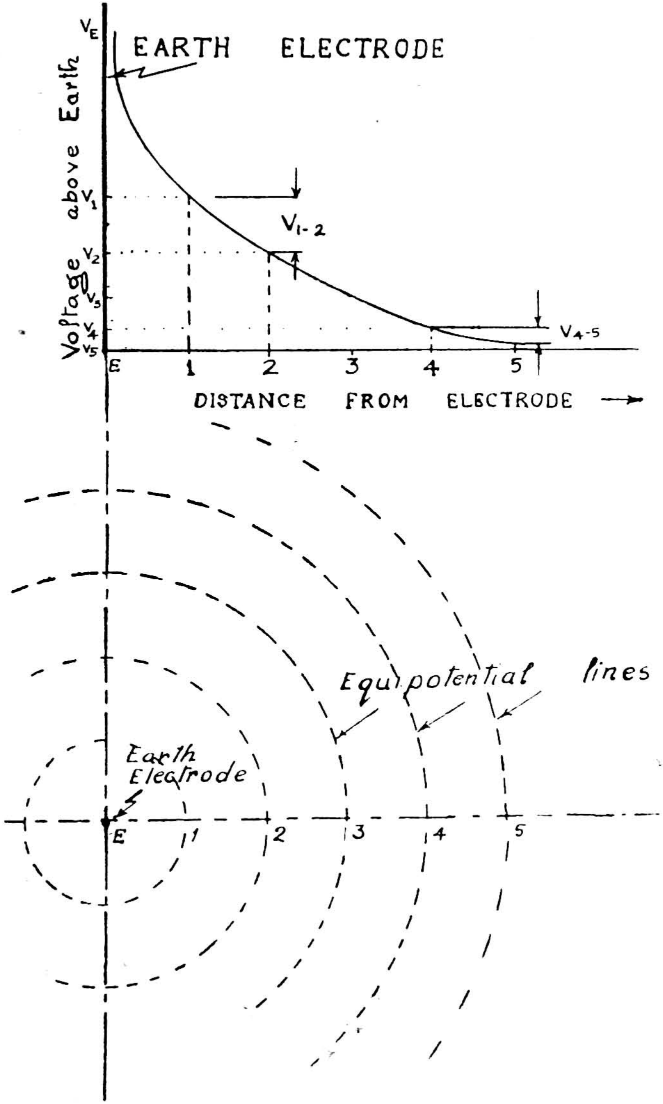

FIG. 1.—Potential gradient under fault conditions.

practice of burying the electrode in a mixture of coke and salt is not considered a good one, as it aggravates cell action and the formation of a gas film around the electrode.

The resistance of the general mass of earth is kept low, as far as possible by silting the "earths" in places where the earth is of low resistance or moist. Where the earth is not good, frequent watering of the earth will be necessary.

(b) *Potential gradient under fault conditions.*—When a current passes between the electrode and earth due to a fault, there will be a voltage drop between the electrode and the general mass of earth. This voltage difference will decrease along a line radiating from the electrode so that there will also be a voltage drop between the elec- on the ground at different distances from the electrode. The conditions existing when a current flows to earth are shown in Fig. 1.

The shape of the voltage curve will depend on such factors as the type and size of the electrode, the nature of the surrounding earth and its resistance, contact between electrode and earth, etc. If the specific resistance of the soil is high and the contact between electrode and earth poor, the potential gradient will be steep. If the soil resistance is low, the potential gradient will be low.

The potential curve can be plotted by passing a test current of required magnitude to earth. A voltmeter is connected with one terminal to the electrode and the other terminal to a test spike which is driven to the earth at various distances radiating from the electrode and the voltage drops measured. The voltage drops are then plotted on a graph against the radial distances from the electrode and the potential curve drawn in.

Equi-potential rings can be drawn with the electrode as centre and radii equal to the voltage drops at various distances from the electrode.

Generally the voltage drop between points on the earth surface say one foot apart will be greater near the electrode. For example, in Fig. 1 the potential difference between points 1 and 2 which is V. 1-2 will be greater than the potential difference V. 4-5 between points 4 and 5, even though the distances between 1 and 2 and between 4 and 5 are the same.

In order to avoid accidents by shock to persons coming in contact with the earth electrode or the earth leads, it is necessary to keep the potential gradient low. When the earth is poor and the potential gradient high, it is possible for persons to receive severe or fatal shocks from earth wires or earth electrodes under fault conditions, that is when fault current is flowing to earth.

(c) *Resistance area of earth electrodes.*—The equi-potential rings or lines radiating from an earth electrode reach a point, where the potential curve flattens out and there is no further noticeable difference of potential. The area enclosed by such a circle is the resistance area of the electrode. In

Fig. 1 the curve flattens out at a distance 5 from the electrode and the area enclosed in the circle with radius E 5 is the resistance area of the electrode. Any two points on the earth outside this area will not have any noticeable or measurable difference of potential between them and all points outside this area can be considered as being at earth potential during fault conditions.

3. *Resistance tests of earth electrodes—(a) Fall of potential method.*—In the fall of potential method, two auxiliary spikes or electrodes Ev, Ec (*see* Fig. 2) are used. The voltage spike Ev is driven in the ground usually about 75 feet from the electrode E under test, and the current spike Ec is driven in the ground at about twice this distance (i.e., about 150 feet) from the electrode E under test. It is necessary that the spikes are fairly widely spaced so that the spike Ev is outside the resistance area of E and Ec. A fairly heavy current is passed between the electrode E under test and spike Ec, while the voltage is measured between E and Ev.

$$\text{The earth resistance of E} = \frac{V}{C}.$$

where V is the voltage between E and Ev and C is the current flowing between E and Ec.

In Fig. 2, the resistance of the electrode E is given by P.R. which is equal to V/C. The resistance of the test spike Ev is given by L.M.

In the two spike method of measuring the earth resistance, the earth tester only records the resistance of the earth E under test and the resistance of spike Ec is not included.

It will be noticed in Fig. 2 that the potential curve flattens out at point S where the voltage spike Ev is situated and the curve at this point lies along the line of earth potential.

(*b*) *Error due to insufficient spacing of test spikes.*—If there is insufficient spacing between the earth electrode under test and the test spikes Ev and Ec, there will be an error in the measurement due to the over-lapping of the resistance areas of E and Ec as shown in Fig. 3. The resistance of the electrode E under test as recorded by the instrument will be P.Q. instead of the true resistance P.R. due to the resistance areas of E and Ec over-lapping, and it will be seen in Fig. 3 that the potential curve cuts the line of earth potential sharply at S instead of flatttening out as in Fig. 2.

4. *Good earths.*—Galvanized iron pipes of size not less than 1½ inch and not less than 6 feet long are commonly used as earth electrodes. Where the resistance of the earth is not low enough, more than one pipe could be used but they should be so spaced that their individual resistance areas do not overlap. The spacing recommended is about 20 feet. It is felt that pipes should be driven into the ground without disturbing the soil as this compacts the soil around the pipe and gives a good contact. Where this

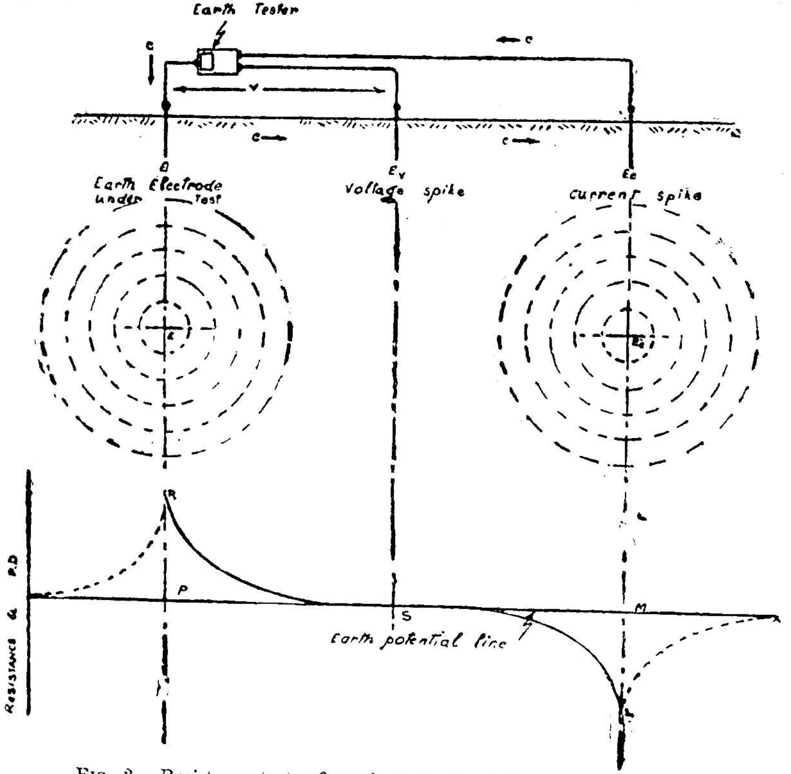

FIG. 2.—Resistance tests of earth electrode; fall of potential method.

is not possible without damaging the pipe, such as in places, where the soil is hard, pits may have to be excavated, for the pipe, in which case the back fill could be of good soil from another location.

The use of coke and salt or the watering of earths with brine solution is not considered good practice, as it not only aggravates the corrosion of the pipe but also tends to cause cell action which results in the formation of a film of gas between the pipe and the earth thus increasing the contact resistance.

The importance of good earthing is sometimes not realized by line construction staff, who sometimes pay little attention to the proper earthing of neutrals of distribution systems, metal line supports, structures and stays, etc. Poor earthing of these parts may cause them to have an appreciable potential above earth, when there is an earth fault or leakage of current to earth. L.T. Distribution systems are not usually provided with earth leakage protection and are normally protected for overloads only, by means

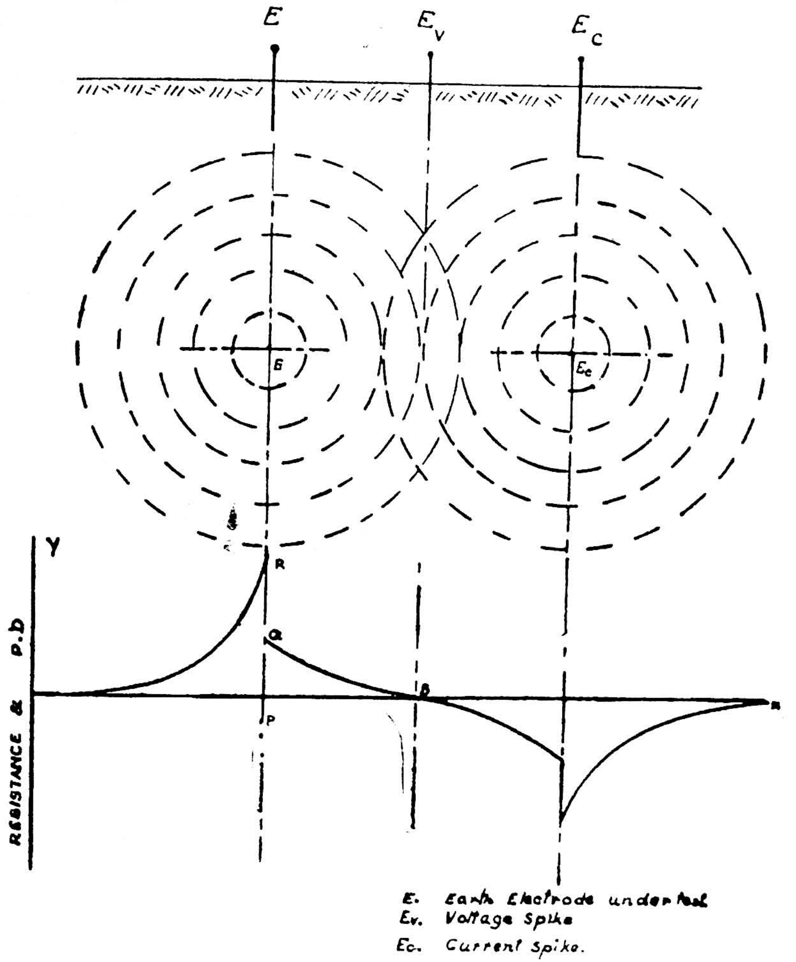

FIG. 3.—Error due to insufficient spacing of test spikes.

of fuse units. The fault current to earth is usually insufficient to blow the fuse at the transformer or section point and isolate the earth fault. A stay in an L.T. Distribution system was once found to have a potential of about 113 volts due to its coming in contact with a live conductor. The leakage current was not sufficient to operate any protective device and isolate the stay.

Limited Range K.V.A.H. Meters

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The H.T. bulk consumers served by the Department are charged on the actual consumption of energy, and also the maximum load demand at the service, measured in *either* K.W. *or* K.V.A. *A trivector* meter is normally installed at the service to indicate energy consumed, the K.W. demand and the K.V.A. demand. The K.V.A. demand is indicated by the trivector meter by summation of fractions of speeds of the active and reactive energy meters and the indication is reliable within an error of one per cent up or down the true value of the demand. The Departmental practice is to instal trivector meters in all services with a demand of 200 KVA and above. In cases where the demand is less, the energy consumed and the K.W. demand are indicated by a K.W.H. meter and this is supplemented by a lagged K.V.A.H. meter if considered necessary. In such cases, the K.V.A.H. meter is capable of indicating the K.V.A. demand only within a certain predetermined range of power factor of load and within this range, there is a small error in the indication of demand, of about 1·5 to 2·5 per cent up or down the true K.V.A. demand. The principle of working of such meters and the method of testing adopted at the Electrical Standards Laboratory are briefly dealt with below.

General Principles.

In a K.W.H. meter, the potential flux lags the applied voltage by an angle somewhat less than 90 degrees. The current flux is nearly but not exactly in phase with the current flowing through the current coil. In consequence, the voltage flux and the current flux are not in exact quadrature, when load power factor is unity. The angle of departure from quadrature is corrected and quadrature relationship obtained by the provision of a suitable lag coil on the electromagnet in the circuit of the flux shunted to the disc. The position is clarified in Fig. 1.

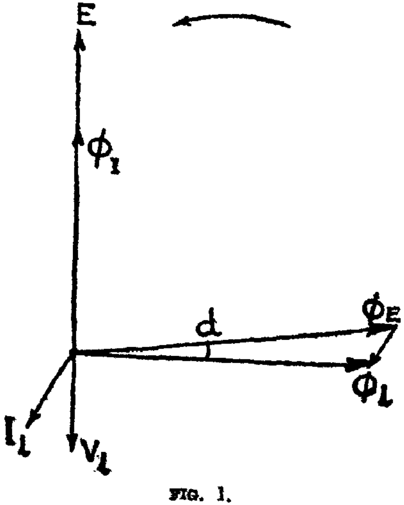

FIG. 1.

In the Figure, E is the applied voltage and I, the load current at unity power factor. $\varnothing_I$ is the flux in the series electromagnet, $\varnothing_E$ is the flux in the voltage electromagnet with an angle of departure from quadrature of angle 'd'. A voltage V_1 is induced in the lag coil, which sets in a current I_1 $\varnothing_1$ is the flux due to the lag coil and $\varnothing_r$ the resultant flux in the disc circuit. The disc flux $\varnothing_r$ is more in quadrature than $\varnothing_E$ with $\varnothing$. The exact quadrature is obtained by inclusion of an adjustable resistance in the lag coil circuit. $\varnothing_r$ is proportioned to $\varnothing_E$. The torque of the meter is proportional $\varnothing_r \varnothing_I$ that is proportional. to EI. When the load power factor is Cos θ, $\varnothing_r$ and $\varnothing_I$ will have a phase difference of $90+\theta$ degrees and the torque will vary as the quadrature component of $\varnothing_r$ and will therefore be proportional to $\varnothing_I \varnothing_r \text{Cos}\,\theta$ or EI Cos θ that is, the power in the circuit.

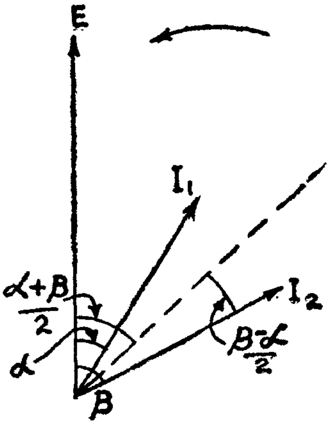

FIG. 2.

A limited range K.V.A.H. meter has a limited range of load power factor, within which alone, it is considered reliable and to record closely the K.V.A. demand. If the power factor range is limited to CosL and CosB, then the mid power factor is designated Cos $\frac{L+B}{2}$ or say Cos m (vide Fig. 2. The meter has a maximum torque, proportional to EI, when the load power factor is Cos m; and a torque proportional to EI Cos (m−n) for a change in the load power factor angle 'n'. The meter will have a torque proportional to Cos $\frac{B-L}{2}$ when the load power factor is Cos L or Cos B. There is therefore an inherent variation from EI to EI Cos $\frac{B-L}{2}$ in recording K.V.A.H. units, when the power factor varies from Cos L to Cos B. The error is small and equal to 1—Cos $\frac{L-B}{2}$ say 'r' per cent. The meter is adjusted in practice, r/2 per cent fast at mid power factor of Cos m, when it would be r/2 per cent slow at the limits of power factor range, namely, Cos L and Cos B.

In the limited range K.V.A.H. meter, therefore, the meter torque is maximum, when the load power

factor is the mid power factor of the meter. For any variation of phase angle from the mid power factor angle, the meter functions exactly similar to a K.W.H. meter. The position is clarified in Fig. 3.

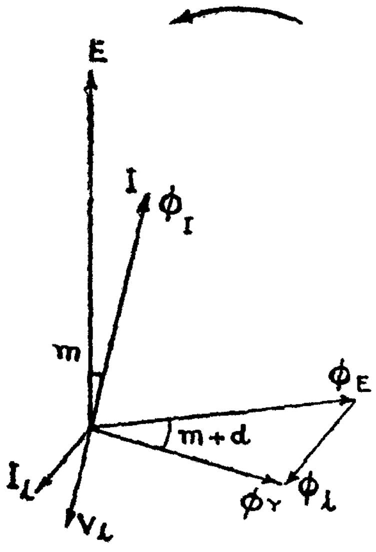

FIG. 3.

In the Figure, E is the applied voltage and I the current at power factor Cos m lag. $\varnothing_I$ is the series flux and $\varnothing_s$ the shunt flux. The disc flux $\varnothing_r$ is proportional to $\varnothing_s$ and lags $\varnothing_s$ sufficiently to offset the mid power factor angle 'm', as well as the angle of departure from quadrature 'd' of the potential flux.

Shift in phase angle flux.

The requisite shift in the potential flux to the extent of the mid power factor angle may be effected by any one of the methods noted below:—

(1) *Overlagging of disc flux.*—In a K.W.H. meter, the angle of departure 'd' from quadrature of the potential flux is corrected by the provision of the lag coil in the circuit of the disc flux, creating thereby an M.M.F. in quadrature with the main flux. If this correction can be carried further so as to cover the mid power factor angle 'm' by overlagging the flux, shunted to the disc, then the disc flux and the series flux would be in quadrature at mid power factor of load.

In Figure 3, V_l is the induced voltage in the lag coil and I_l the induced current: $\varnothing_l$ is the flux due to the lag coil and $\varnothing_r$ the resultant flux in the disc circuit.

$\varnothing_r$ is proportional to $\varnothing_s$, and is adjusted to be in quadrature with $\varnothing_I$. Torque is proportional to $\varnothing_r$, $\varnothing_I$ or EI at mid power factor. Connections to the 3-phase K.V.A.H. meter are the same as for a normal 3-phase K.W.H. meter, the red element of the meter being connected to the potential supply E_{BY}: and blue element to E_{BY}

(2) *Choice of phase to neutral voltage.*—If the meter is provided with 3 potential core-magnets, and the coils are connected in star, and to the mains each coil will get a supply shifted in phase by 30

degrees lag, from the phase to phase voltage. The core flux would therefore lag the phase to phase voltage by 30 degrees. The 30 degrees shift in disc flux so obtained can be maintained and modified by provision of quadrature loops involving—

(*a*) underlagging of disc flux

(*b*) correct quadrature lagging, or

(*c*) overlagging of disc flux.

The *total shift* can thus be made equal to the mid power factor angle. Case (*a*) is suited to mid power factors less than 30 degrees lag; case (*b*) is suited to a mid power factor of 30 degrees lag; and case (*c*) to a mid power factor exceeding 30 degrees lag.

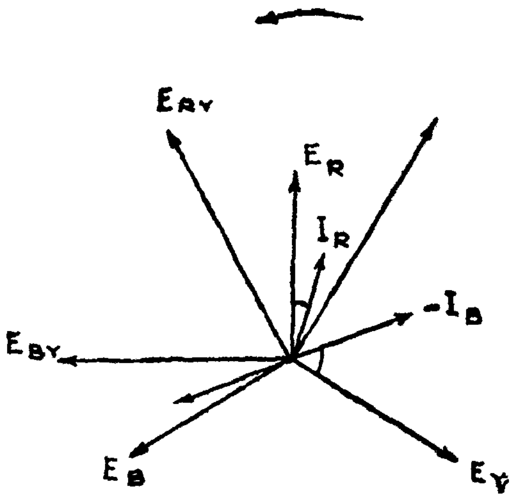

FIG. 4.

Fig. 4 gives connections to a 3-phase meter. The red element is given 'R' current in the correct sequence and voltage E_R lagging E_{RY} by 30 degrees. The blue element is given 'B' current reversed and voltage E_Y lagging E_{BY} reversed by 30 degrees. The middle element has the voltage magnet but no current magnet. As the potential coils have a supply of about 63·5 volts only, coils of this voltage would be used in the meter. The meter is also a 3-element meter. The under-lagged meter may have no lag coil at all and the potential coil by itself may give the requisite additional shift in the disc flux. Meter connections are given in Fig. 5.

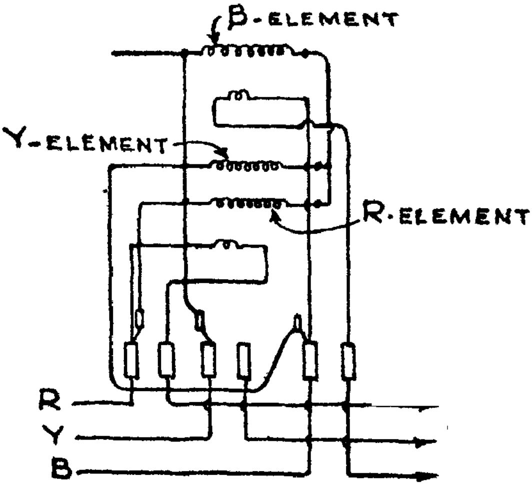

FIG. 5.

(3) *Choice of a lagging phase voltage.*—By connecting the red element potential coil to voltage E_{RB} and the blue element potential coil to E_{RY} instead of E_{RY} E_{BY} respectively, the voltage supply to the two coils can be made to lag by as much as 60 degrees compared to a K.W.H. meter connected to voltage E_{RY} and E_{BY}—vide Fig. 6. This shift can then be combined with under-lagging, correct lagging or over-lagging of the disc flux to give any desired shift below, equal to, or above 60 degrees.

Normally, however, the mid power factor of a K.V.A.H. meter would only be about 30 degrees. In such a case, the potential coil may be made sufficiently resistive by inclusion of an external resistance, if necessary, as to make the potential flux lag the applied voltage by about 60 degrees instead of nearly 90 degrees as usual.

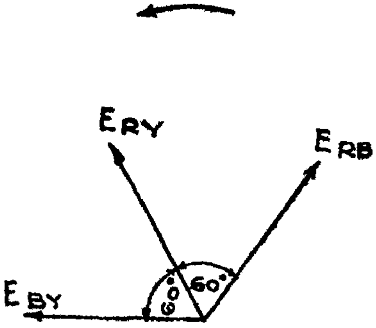

FIG. 6.

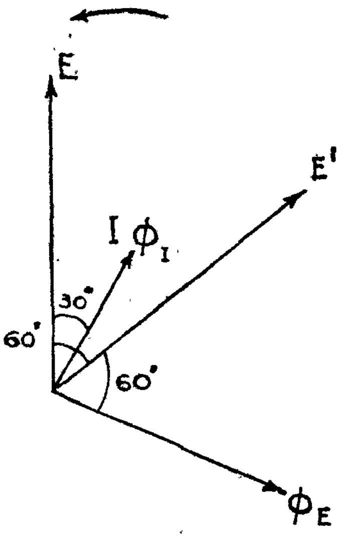

FIG. 7.

In Fig. 7, E is the voltage normally applied to a K.W.H. meter. Instead of E, voltage E lagging E by 60 degrees is now applied to the meter potential coil. Flux $\varnothing_E$ lags E by 60 degrees. Load current I lags by 30 degrees, the power factor being 30 degrees lag; $\varnothing_I$ is seen to be in quadrature with $\varnothing_E$. The meter therefore develops maximum torque, when power factor is 30 degrees lag and the meter behaves as a K.V.A.H. meter for variation about 30 degrees lag power factor.

An M.V. RKVAH., R.S.S. is an instance of a meter with 60 degrees shift by voltage choice mentioned above. This meter can therefore be connected to be a K.V.A.H. meter with the mid power factor of 30 degrees lag.

(4) *Shunting current coil by inductance.*—One method of getting the quadrature relationship between the potential flux at the disc and the series flux is to shunt the current coil of the meter by a suitable inductance.

In Fig. 8, E is the voltage applied to the potential coil and $\varnothing_E$ is the flux with a small angle of departure from quadrature of 'd'. I is the current in the circuit at mid power factor angle 'm' of meter. When the current coil is shunted by an inductance, a lagging current I_I will flow through the inductance and the balance of current I_C will flow through the current coil of the meter. The angle of lag of current I_I can be controlled by inclusion of an adjustable resistance, in the inductance circuit. The current I_I is so adjusted that I_C makes an angle of (m + d) with I. $\varnothing_I$ will then be inquadrature with $\varnothing_E$ and the

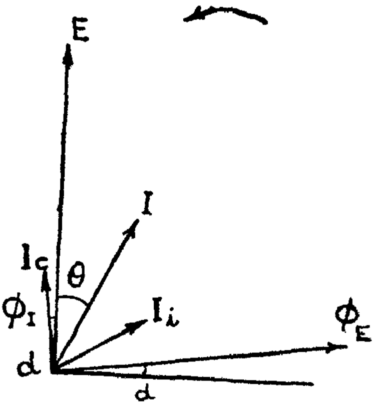

FIG. 8.

meter develops maximum torque, at the mid power factor angle of the meter. As, I_E is proportional to I. current flux $\varnothing_1$ is proportional to I and the torque is proportional to $\varnothing_I \varnothing_E$ that is proportional to EI.

The 3 phase meter will be connected similar to K.W.H. meter with potential E_{RY} to the red element and E_{BY} to the blue element.

(5) *Use of an auto-transformer.*—An auto-transformer can be used to get the necessary phase shift in the voltage supply to the potential coil of the meter.

RYB is the 3-phase auto-transformer. Winding BR is extended to R_1 and a tapping point Y_1 is chosen in the winding BY such that the voltage between R_1 and Y_1 is equal to the line voltage RY and YY_1 makes an angle θ with RY. If $BY_1 = x_E$

$$\frac{BY_1}{R_1Y_1} = x = \frac{\text{Sin}\,(60-\theta)}{\text{Sin } 60}$$

$$= \frac{2}{\sqrt{3}}\,\text{Sin}\,(60-\theta)$$

Also if $BR_1 = Y_E$

$$\frac{BR_3}{R_1Y_1} = Y = \frac{\text{Sin}\,(60+\theta)}{\text{Sin } 60}$$

$$= \frac{2}{\sqrt{3}}\,\text{Sin}\,(60+\theta)$$

Similarly, winding RY is extended to Y_2 and a tapping point B_1 chosen in BR such that the voltage between $B_{\cdot 2}$, Y_2 is equal to line voltage E and B_2 Y_2 makes an angle θ with BY.

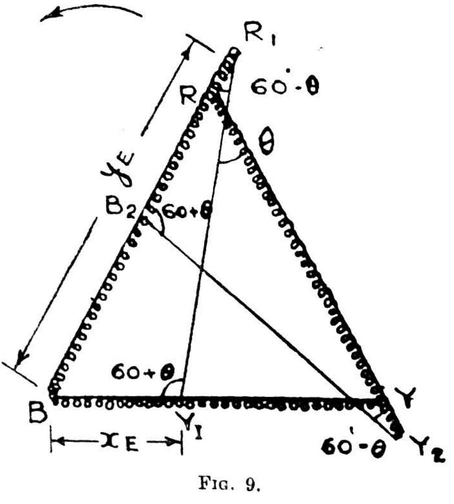

FIG. 9.

Here also $RB_2 = xE$ where X

$$= \frac{2}{\sqrt{3}} (\text{Sin } 60 - \theta)$$

and $RY_2 = yE$ where

$$y = \frac{2}{\sqrt{3}} \text{Sin } (60 + \theta)$$

Red element of the meter is connected to $R_1' Y_1'$ instead of RY and the blue element connected to $B_2 Y_2$ instead of to BY. As $R_1 Y_1$, Y_2B_2 lag behind RY, BY respectively by an agle equal to the mid-power factor angle the meter behaves as a KVAH meter and the KWH meter is directly used without any internal additions or alterations.

When $\theta = 30$ degrees.

$BY_1 = RB_2 = E/\sqrt{3}$; also

$BR_1 = RY_2 = 2E/\sqrt{3}$

Using of the auto-transformer so connected the K.W.H. meter can be used directly as a K V A H meter with mid-power factor angle of 30 degrees. For variations in the mid-power factor angle near—about 30 degrees, the meter may be adjusted internally by using suitable quadrature loops.

When θ is some angle, other than 30 degrees, but close to the mid-power factor angle of the meter then again the meter may be adjusted internally by using suitable quadrature loops.

If it is desired to replace the three-phase auto-transformer by two single-phase auto-transformers connected to two phases only, suited to an open—delta potential transformer supply, the arrangements of windings on the transformer would be as given in Fig. 10.

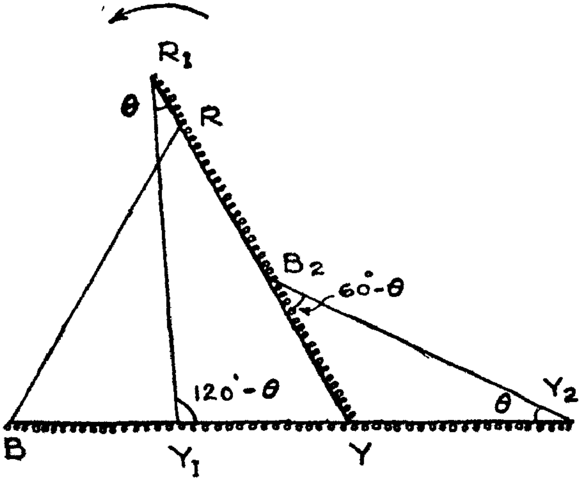

FIG. 10.

In the Figure there are two transformers shown namely RY, BY. Winding YR is extended to R_1 and a tapping Y_1 chosen in BY such that the voltage between R_1 and Y_1 is equal to the line voltage E and R_1Y_1 makes an angle with RY.

If $YY_1 = X^1E$

$$\frac{YY_1}{E} = \frac{\text{Sin}(60 - \theta)}{\text{Sin } 60}$$

i.e. $x^1 = \frac{2 \text{ Sin}(60 - \theta)}{\sqrt{3}}$

If $YR_1 = y'E$

$$\frac{YR_1}{E} = \frac{\text{Sin}(120 - \theta)}{\text{Sin } 60}$$

i.e. $y^1 = \frac{2 \text{ Sin}(120 - \theta)}{\sqrt{3}}$

Similarly winding BY is extended to Y_2 and a tapping B_2 chosen in RY, such that the voltage between B_2 Y_2 is equal to the lines voltage E, and B_2Y_2 makes an angle θ with BY.

If $YY_2 = x'' E$

$$\frac{YY_2}{E} = \frac{\text{Sin}(60 - \theta)}{\text{Sin } 60}$$

$x'' = \frac{2 \text{ Sin}(60 - \theta)}{\sqrt{3}}$

If $YB_2 = y''E$

$$\frac{YB_2}{E} = \frac{\text{Sin } \theta}{\text{Sin } 60}$$

$y'' = \frac{2 \text{ Sin } \theta}{\sqrt{3}}$

Here again the red element of the meter is connected to R_1Y_1 instead of RY and the blue element connected to B_2 Y_2 instead of to BY. As R_1 Y_1; B_2 Y_2 lag behind RY; BY respectively by an angle equal to the mid-power factor angle, the meter behaves correctly as a K.V.A.H. meter about the mid-power factor.

Choice and accuracy.

Choice of method of shift.—The L and G make KVAH meter utilizes the inductive shunt for getting the necessary shift within the meter. The C & H Ferranti and M.V. makes utilize lagging coils of suitable size and 30 degrees shift. The 60 degrees shift by choice of voltage and inclusion of series resistance is used in M.V. RKVAH. R.S.S. The C & H, RKVAH meter uses auto-transformer to get the shift.

Accuracy of registration.—It has to be understood that the error of plus or minus 2 to 2·5 per cent is inherent in the construction of the meter itself, and it is essential that the load power factor does not vary beyond the limits of variation permissible for the meter, for the meter-registration being reliable.

Method of test.—The usual method of testing a K.W.H. meter against a K.W.H. R.S.S. meter cannot be adopted for testing a K V A H meter unless the mid-power factor angle and the limits of power factor range can be accurately set and maintained on the test table. This is a somewhat difficult process. The method of testing adopted at the Electrical Standards Laboratory would be dealt with in a succeeding article.

Progress during the Quarter ending 30th September 1955

Salient features.

The operation and maintenance of all the systems was satisfactory. The inflows in the Pykara and Mukurthi Reservoirs during the quarter were satisfactory. The inflows in the Mettur and Papanasam Reservoirs were poor in the earlier part of the quarter but improved in the latter part and the position became fairly satisfactory.

The Department earned a revenue of Rs. 169·02 lakhs during the quarter. The working expenses amounted to Rs. 65 lakhs. The capital expenditure during the quarter was Rs. 154·15 lakhs.

Supply was given to 1,763 agricultural services, 144 industrial services and 6,415 domestic services.

The number of villages electrified during the quarter was 145. Also 151·5 miles of H.T. and 320 miles of L.T. lines were constructed and energised during the quarter.

Construction Branch.

Pykara Plant Extensions III Stage.—Progress in the dam masonry and earth bund was slow due to monsoon rains. Arrangements were being made to concrete the spillway to enable further work being carried out as soon as the rainy season was over.

Madras Plant Extensions.—Under I stage the erection of the mulsifyre protection equipment was nearing completion. All other equipments had been commissioned.

Under the III stage, all necessary equipments at 'A' station were shifted to make room for the III stage works. The dismantling of the concrete and steel works continued progress. Piling frame was erected and piling commenced for the foundation.

Periyar Hydro-Electric Scheme.—Land acquisition for the project was in progress. Major portion of the roads in the project area was completed. Temporary staff quarters in both the upper and lower camps were completed and permanent quarters were under construction.

In the power tunnel about 930 feet out of a total 4,190 feet has been tunnelled during the quarter.

Excavation for foundation for the forebay dam, and the grading of penstock slopes, were in progress. Levelling of power house site, transformer yard and tail race was completed. Excavation for the foundation of the power house was taken up.

Transmission Lines—(i) *Salem-Namakkal* 110 *KV line.*—Construction of staff quarters at Rasipuram and Namakkal was in progress. The construction of transmission lines had already been completed.

(ii) *Singarappet-Villupuram* 110 *KV line.*—Tower erection in the Singarappet-Tiruvannamalai section had been completed. Check survey, tree clearance, excavation of pits, stub-setting and tower erection were in various stages of progress in the Tiruvannamalai-Villupuram section.

(iii) *Singarappet-Vellore* 66 *KV line.*—Check survey and tree clearance were nearly completed; 82 per cent excavation and 80 per cent of stub-setting were completed. Line materials, towers, conductors, earth wire, etc., were being received at site.

(iv) *South Kanara Scheme.*—On the Hulikal-Mangalore 110 KV line, all works had been completed, except provision of revetment in certain tower locations.

Work on the Udipi-Hiriadka-Karkala 33 KV line was completed and line handed over to operation, with Karkala being supplied from Udipi.

All works on the Udipi-Coondapur lines except erection of terminal structure at Udipi and stringing of half a mile of line, were completed. Supply to Coondapur was effected from Udipi at 11 KV by making use of a portion of the new lines from Brahmavar to Coondapur and connecting it to the existing line from Udipi at Brahmavar.

Construction of staff quarters for various sub-stations and R.C.C. structures for sub-station structures was in good progress.

(v) *Villupuram-Pondicherry* 66 *KV line.*—Alignment, levelling and plotting of the route were completed.

(vi) *Periyar Transmission lines*—(*a*) *Theni-Sembatti* 110 *KV line.*—Survey was completed. The contract for the construction of the line was awarded to Messrs. S.A.E. (India), Limited. Tree valuation was under progress by the Revenue Department.

(*b*) *Periyar-Theni-Madurai* 110 *KV line.*—Survey work, plotting of profiles and preparation of tree valuation schedules are in progress. Contract for the construction of the line was awarded on contract to Messrs. S.A.E. (India), Limited. The site for the Theni sub-station was handed over to the contractor.

(*c*) *Sembatti-Karur* 66 *KV line.*—Reconnaissance was completed and survey work was in progress.

(*d*) *Sembatti-Trichy* 110 *KV line.*—Approval of the route by the Power Tele-communication and Co-ordination Committee is awaited.

(vii) *Madukkarai-Palghat* 66 *KV line.*—The fabrication of poles and structures was in progress and 70 D.P. structures were erected.

(viii) 110 *KV line from Travancore-Cochin border to Udumalpet.*—The extension was sanctioned during the quarter and detailed survey of the line was taken up.

Operating Systems.

Hydro Systems.

(*a*) *Generation.*—The station peak load, the system peak load and the units generated during the quarter were as follows:—

Name of system/ station. (1)	Station peak load in M.W. (2)	Units generated in millions. (3)	System peak load in M.W. (4)
Pykara	68·7	85·606	58·6
Moyar	36·0	36·081	
Mettur	40·3	64·489	61·2
Papanasam	28·0	38·200	25·8
Madurai Thermal Station	3·5	0·257	
Udipi	0·323	0·194	0·3

The following services were connected during the quarter:—

System (1)	Agricultural. (2)	Industrial. (3)	Domestic. (4)
Pykara	764	29	2,400
Mettur	639	18	1,099
Papanasam	239	18	1,816

The Karkala station was closed down and supply taken from Udipi station. The storage position in the Mukurthi and Pykara reservoirs continued to be satisfactory, while in the Mettur and Papanasam reservoirs the inflows were poor during the greater portion of the quarter. However, normal generation in all the power houses was maintained. The turbine floor of Papanasam Power House got flooded on 25th September 1955 at 16–35 hours due to inadvertent opening of the C.B. valves and the power house had to be shut down for 36 hours. Normal conditions were restored expeditiously.

The annual overhaul of No. 2 and No. 3 machines of Pykara Power House was carried out. The mulsifyre protection works at Mettur Power House were under progress.

The 10 MW. turbo set as Madurai thermal station broke down on 24th July 1955 owing to temporary blocking of oil supply to the bearings. Rectification work was immediately taken under the supervision of Messrs. Hitachi, Limited.

(*b*) *Distribution—Pykara System.*—The second 3,000 KVA transformer was erected at Udumalpet in the place of 1,750 KVA unit which was transported and commissioned at Tiruppur substation as the additional fourth unit at the station.

Works on the Somanur-Puliampatti 66 KV line and the Puliampatti-Shenbagapudur 33 KV extensions were in advanced stages of construction.

Ingur-Oalapalayam 33 KV extensions were in progress.

On the Cannanore-Badagara-Quilandi extensions the Cannanore-Badagara line was nearing completion.

Mettur System.—The construction of Vellore-Arni 66 KV line was completed.

The 33 KV θ OCB was erected at Arni sub-station to control the Arni-Mambakkam 33 KV line.

Mulsifyre protection work at *Mettur Power House was in progress.*

Papanasam System.—When the turbine floor got flooded and the power house was shut down system supply was maintained by taking relief from Pykara System. Supply to the H.T. consumers in the system was restricted during the period. The shut down was availed to attend to masonry repairs to the revetment on the tail-race channel.

Thermal System,

Madras System.—The station peak load, system peak load, and units generated during the quarter were as follows:—

Name of station.	Station peak load in M.W.	Units generated in millions.	System peak load in M.W.
(1)	(2)	(3)	(4)
A Station	20·8	15·247	38·0
B Station	14·8	16·186	

The C Station was dismantled and transported to Neyveli to be re-erected there by the Central Water-Power Commission for meeting the power demand of the lignite mining. The services connected during the quarter were as under:—

Agricultural	..	121
Industrial ..	..	49
Domestic ..	..	1,105
Total	..	1,275

Also 633 services with a connected load of 819 KW were changed over on a voluntary basis from D.C. to A.C. Overhaul of the boiler Nos. 7 and 9 at 'A' station and boiler No. 2 at 'B' station was completed.

Major construction works as below were in progress in the distribution:—

(i) Laying of 11 KV 0·25 square inch cable, from Kilpauk sub-station to Egmore sub-station; from Power House to Crooks Road sub-station and thence to Kilpauk sub-station; from Power House to Egmore sub-station and thence to Mount Road sub-station;

(ii) laying of 11 KV 0·15 square inch cable from Kilpauk sub-station to Chetput sub-station;

(iii) laying of 11 KV 0·10 square inch cable from Sembiam R.S. to Sembiam sub-station and from Nungambakkam sub-station to Chetput sub-station, etc., and

(iv) a number of rural extensions in the Chingleput district.

Rural Electrification.

The number of villages electrified during the quarter in the various systems was as follows:—

Pykara System	87
Mettur System	26
Papanasam System	16
Madras System	16
Total ..	145

The length of lines constructed and brought into beneficial use during the quarter under the various schemes of rural electrification are as follows:—

System.	H.T. in miles.	L.T. in miles.
(1)	(2)	(3)
Pykara	48·58	121·05
Mettur	59·21	135·90
Papanasam ..	18·94	35·71
Madras	24·82	23·76
Total ..	151·55	320·42

Accounts Branch.

The Department earned a revenue of Rs. 169·02 lakhs during the quarter. The working expenses during the quarter including suspense and the annual contribution of Rs. 123 lakhs to depreciation and special reserve amounted to Rs. 198·41 lakhs. The working expenses deducting the annual contribution will therefore be only Rs. 65·41 lakhs against Rs. 87·62 lakhs in the previous quarter.

The capital expenditure during the quarter including suspense was Rs. 154·41 lakhs and the capital expenditure for the current year to the end of September 1955 amounted to Rs. 224·06 lakhs.

The following loan contributions were received in the various systems:—

System.	Rupees in lakhs.
(1)	(2)
Pykara	11·00
Mettur..	3·84
Papanasam	2·96
Madras	18·90
Total ..	36·70

Technical Branch.

(A) *Electrical Branch.*—Tenders for transformers and out-door switchgear for Periyar Power House and Power transformers for the sub-stations under the Periyar Hydro-Electric Scheme were analysed and orders were placed.

Tenders for supply of line materials and erection of line from the Travancore-Cochin border to Udumalpet were received and were under scrutiny. Orders for supply and erection of cooling water system and for the supply of switchgear required for Madras III Stage Extensions were placed. Orders were also placed for Distribution transformers and line material required for the rural electrification schemes.

(B) *Civil Branch.*—Under the Madras III Stage Extensions, tenders were awarded for the construction of cooling towers, pile foundations for the main power house extensions and buildings steel works.

Under the Periyar Hydro-Electric Scheme, designs for the pipe tunnel were finalised. Negotiations were conducted with

Messrs. Patel Engineering Company, the contractors for the power tunnel to carry out the improvement works of irrigation tunnel. Tenders received for the penstocks and for the 100-ton electrically operated travelling crane for the power house were under scrutiny.

Collection and compilation of rainfall and run off data for the various basins and rainfall figures obtained from other departments and private estates were continued. Four additional rainfall stations were erected and commissioned during the quarter bringing the total to 487 rainfall stations.

Second Five-Year Plan.—The plan amount has since been revised to Rs. 61·1 crores for power schemes. Various detailed statements giving phasing of expenditure, targets, additional employment, materials required, etc., were prepared and submitted to Government as required.

Social and Personal

Sri G. Sundaram, Consulting Engineer to Government (Electrical) and Sri S. R. Krishnamurthi, Consulting Engineer to Government (Civil) relinquished office on 31st March 1956 afternoon on the expiry of their contracts.

Sri R. Subba Rao and Sri N. Subramanian, Assistant Engineers (Electrical) were promoted as Divisional Electrical Engineers.

Sri A. M. Ramalingam, Divisional Electrical Engineer and Sri P. Ramamurthy, Assistant Engineer (Electrical) proceeded on deputation to Australia on 8th February 1956.

Sri G. S. Rajan, Executive Engineer (Civil) was promoted as Superintending Engineer (Civil) and posted as Superintending Engineer, General Construction Circle, Tiruchirappalli, vice Sri G. Venkataraman.

Sri G. Venkataraman, Superintending Engineer, General Construction Circle, was transferred as Superintending Engineer, Kundah Hydro-Electric System, Coonoor.

Sri D. Krishnaswami, Assistant Engineer (Civil) was promoted as Executive Engineer (Civil).

Demise

The Department records with deep regret the sudden demise of Sri P. S. Swaminathan, Assistant Engineer, and offers its sympathy and condolence to the bereaved family.

Technical Press

Harness the Engineers.

With the present tempo of country's development projects, shortage of experienced engineers of different categories, to fully man the various projects, is being keenly felt. This shortage is natural when the number of magnitude of works now desired to be executed in the course of a year far exceeds, what we would formerly have thought of executing even in twenty. It is, therefore, very necessary that we should so equip our engineers, that they are able to execute successfully the projects that they may be called upon to handle.

Adoption of suitable measures to that end should therefore be considered as much the duty and responsibility of the heads of the Public Works Departments in the various States as successful execution of the projects now in hand. The Public Works Departments must take steps to ensure that the benefit of experiences being gained and techniques being learnt on different projects is widely shared by the profession in general and is not kept confined to the few actually employed or closely associated with particular projects.

There are two ways of achieving this. One is by exchange of officers between different States so that the knowledge and experience gained in one part of the country is shared by engineers hailing from other parts of the country and the other by compiling and publishing proper records of the various places of projects undertaken and completed.

All projects and parts of the country have their peculiarities and problems. A knowledge of the manner in which different parts of the country are successfully tackling their problems widens one's outlook and helps in the evolution of simpler and more economical methods by a synthesis of experiences and practices of different parts of the country.

We are eager to send our young men for training abroad, but seldom entertain the idea of sending them for training to other parts of the country itself beyond casual visits of a couple of days. Short visits to works in different parts of the country, though useful up to a point, cannot be a substitute for the experience and knowledge that can be gained by actual detailed study of the projects at site during different phases of investigations, designs, planning and construction.

This training can be very much simplified and made more effective by placing the knowledge within reach of all by compiling and publishing complete records of the projects executed, which serve as useful guides both for the engineers and the Governments for proper planning and execution of future projects.

Previously, writing of technical or professional papers was not only encouraged but actually demanded of the officers in-charge, who were given all the necessary facilities for the purpose. These reports gave the history of the projects from their original conception to the various stages of development, changes from the original scope to the ultimate scope and reasons therefor, discussions of the relative merits of the various alternatives of locations and designs and those finally accepted and adopted, the construction schedule, the plant and machinery employed, rates and costs of various items and works and other technical details which served not only as a guide for future works but also as valuable technical literature for the training of engineers.

To illustrate specifically, a report on a dam project would necessarily discuss the various dam sites examined, the considerations leading to the final selection of the site, the hydrology of the catchment, the considerations leading to the fixing of a particular height of the dam, its dead and live storage capacities, the spillway capacity, the particular alignment adopted, the construction, plant layout, the capacities and specifications of the plant and machinery employed, the construction schedule, the maximum and average out-turns, the actual costs, analysis of costs, design details the nature and strength of staff employed, laboratory equipments, transport arrangements made and score of other data which can be of immense use in planning and executing other projects.

Writing of such a report requires quite a bit of time and labour of some senior officer who may have been associated with the project for a fairly long time. If we grudge the time and labour required, for writing such detailed reports for the benefit of engineers taking up other projects, we will always be wanting the necessary quota of experienced hands to undertake new projects whereas with the guidance of detailed reports of completed projects, new projects can be successfully entrusted to officers who may not have the benefit of personal experience without the risk of their making serious mistakes in planning or ordering wrong equipment and the country incurrin infructuous expenditure.

When a new project is undertaken, the officer in-charge of the project has to spend a lot of his valuable time and that of his staff in searching out the required relevant data of other projects to enable him to frame his estimates and construction schedules correctly: which could, if the records of previous completed projects were properly-compiled and readily available, be usefully spent in pushing the actual construction work with much less staff in the initial stages.

A lot of information remains buried in office files, which it is seldom possible for people, without personal knowledge of the existence of such records, to lay their hands on. It is therefore very desirable that the assignment of producing the required report of a project on its completion, should be made

right from the very start by appointing special staff for the purpose for collecting and suitably arranging the necessary record from the very beginning.

We have successfully handled, and are handling projects of such a varied and complicated nature, that by planned interchange of officers and careful recording of our experiences of the projects in different parts of the country, there should be no difficulty in our enabling our engineers to handle future projects with confidence. Through printed reports, the benefit of experience of our projects can be made available to the profession, as a whole, whereas without such reports the experience and knowledge gained on different projects will remain confined to those, who have actually been employed on those projects or have had the benefit of being closely associated with them.

—*Abstract from the Journal of the Central Board of Irrigation and Power, April* 1955.

Cheap Electricity through New Process.

British, American, German and Soviet scientists are engaged in a secret race to produce cheap electricity through " cold combustion " of fuels, Prof. Edward Justi said.

The research was being carried out in even greater secrecy than the research into atomic energy.

Prof. Justi, who is Director of Brunswick Technical University's Institute for Applied Physics, demonstrated his " cold combustion " theory before an audience of several hundred scientists, political and cultural leaders at Mainz in Western Germany on October 28. He produced an electric current by combining oxygen and hydrogen in a " fuel element ".

Prof. Justi told the audience at the Mainz demonstration that the " fuel element " which operated without igniting the fuels had an efficiency ratio of 70 per cent compared with the 40 per cent efficiency ratio of the internal combustion engine.

" The Hindu ",
8th November 1955.

Don't point fan at yourself.

Do you ever try to bear the heat of a summer's day by pointing an electric fan at yourself—and do you have a stiff neck or a sore shoulder the next day?

If the answer is " yes ", you've learned the hard way that yours is not the best method of using a fan to make humid weather more bearable.

But perhaps you never realized that there is good scientific fact behind the recommendation, made by the General Electric Consumers Institute, that you set your electric fan a short distance from you, on a window sill or a table or even on the floor, and aim it away from you before you turn it on. The air will be moved in a circular motion around the room, but only a gentle breeze will reach you. You'll feel refreshed, without being chilled.

Pointing a fan directly at any one is inavisable, because the movement of air at a high speed across the human body results in

an excessive loss of body moisture and heat, leading to a congestion of blood circulation and the inevitable stiff neck.

If you're resting, air moving faster than 50 feet per minute is moving too fast for comfort. Even when you're working hard, you'll feel uncomfortably chilly when the air velocity exceeds 500 feet per minute—and fans deliver air at higher speeds than that.

" *Science digest* "
August 1953.

Electric Power Transport.

Faced by the need to transport electric power over greater distances, *Electricite' de France* has decided to construct a 420,000 volt power line to connect Paris with the production centres in the Alps. The new line will almost double the present tension of 220,000 volts.

Later plans call for extending this new line (Malgovert-Genissiat-Plessis-Gassot) on into Italy, thus making it the first arm of a contemplated European network. Contracts for exchange of Power have already been signed among several European countries, within the framework of the U.C.P.T.E. (Union pour La Coordination de la Production et du Transport de l'Electricite').

Circuit-breakers for the new line will contain a small quantity of oil, and will have a capacity of 12,000 M.V.A. They will be built by the *Ateliers de Constructions Electriques de Delle* (*Compagnie Generale d'Electricite*) which has done similar work for the world's first 400,000 volt power line in Sweden. Another branch of the Compagnie Generale d'Electricite', the *Savoisienne* (Aleliers de Construction de Transformateurs) has received an order for four single-phased auto-transformers; each unit will weigh over 150 tons.

Thermal Power Station in Turkey.

The president of the Turkish Republic, Mr. Djelal Bayar and the Prime Minister, Mr. Adnan Menderes, laid the first stone last October for the new Thermal Power station at Soma, about 62 miles north-east of Izmir. The power plant which is being constructed under the direction of the French Alasthom Company, with the collaboration of the Societe Generale d'Enterprises, the Societe Stein et Roubaix and Cogelex, will operate on lignite. The intial power output will be 44,000 KW, and is to be increased later to over 60,000 KW.

(French Economic and Technical Bulletin—Circulated by the Trade Commissioner for France in Madras.)

Dated 18*th April* 1956.

New Electromagnetic Transducer System.

The Salford Electrical instrument electro-magnetic transducer system comprises an electro-magnetic measuring head and a recorder controller or a special moving coil instrument of the dynamometer type. No electronic valves, barretters, rectifiers or magnetic amplifiers are used, and the equipment is independent of mains supply variation. The transducer measuring heat consists

essentially of a magnetic core mounted between two coils on a spring-loaded shaft. Any movement of the stylus on the end of this shaft displaces the magnetic core and causes a variation in the magnetic flux. The circuit is so arranged that the controller or indicating instrument then automatically adjusts itself so that this variation is balanced out, Mechanical displacement of less than 0·001 inch can be measured directly with this system.

Another important application is for the measurement of turbine expansion characteristics. It can be used to measure both the absolute longitudinal expansion of the turbine casing and, in certain cases (for example with G.E.C.2 casing high output sets), the differential axial expansion of the shaft in relation to the casing. When used in conjunction with a recorder, the transducer system can, therefore, provide a valuable record of the expansion characteristics of a turbine during, for example, its running up period and may even enable this period to be reduced.

A typical application in this field is on a 30 MW. G.E.C. turbogenerator in which two transducers are used. One is mounted on a bracket attached to the turbine casing so that the measuring stylus bears directly on the pedestal supporting the turbine. When the temperature of the casing rises and it expands, the body of the measuring head being attached to the casing moves longitudinally away from the pedestal. The spring-loaded stylus continues, however, to bear against the pedestal and the transducer system converts the resulting internal displacement within the measuring head into a variation in magnetic flux, which is reproduced as a recording on an instrument reading on the control panel. The other transducer measuring head is mounted on the end of the casing so that the stylus bears directly on the end of the turbine shaft. It therefore records the differential axial expansion of the shaft in relation to the casing. The transducers are available for a variety of different ranges and enable readings to be taken, which are accurate to within one per cent of the full scale reading. A variety of smaller and larger ranges is available, the accuracy in all instances being within about one per cent of the full scale reading.

"*The Hindu*",
13th November 1955.

Low Voltage Soldering Tool.

A new low-voltage soldering tool has recently been made available, suitable for every type of soldering. The design is based on the principle of heating the job direct, which is achieved by insulated tong leads conveying the electric current to the special type of carbon electrodes. To make a soldered joint the parts are held in the Venum tongs, providing in effect an extra pair of hands, the button is pressed, the solder run, the button released, and the joint is made. The absence of pre-heating avoids burns and fires. Heating does not occur until the tool is actually in contact with the work and then only at the will of the operator. The tool cools again

within a few seconds, and the stems are insulated against shorting.

The arms and electrode holders of the tool are detachable and interchangeable, which, together with the special carbon electrodes, enables all types of work to be handled, whilst many otherwise inaccessible positions can be easily reached. Dismantling of parts to be soldered is reduced to a minimum because the quick-action localised heat does not harm adjacent insulation.

The Venum is designed for use with 6-volts but may be used up to 12-volts by skilled operators. The current consumption is very low. In any case, the current is only required for a few seconds, owing to the fact that no-pre-heating is necessary.

The same tool can be used for soldering solid material of from 1/64th to ½ inch diameter, or equivalent surfaces, in copper, brass or other solderable metals, ranging from the lightest radio and electrical connections to heavy logs, copper tubes and strips, Floating wires can be held steady and soldered without the necessity of an assistant, vice or other means of securing, whilst the soldering job is being done. When it is not practicable to use the tong action the electrodes can be adjusted by turning the stems with the special tool so tha the faces fit as squarely as possibl on the work to be soldered. The equipment provided with the tool includes both square and round electrodes, the latter being for use where the job cannot be gripped and a forward application of heat is desired, or where access to th soldering position is restricted. They are especially useful when the tool is being used as an earth-return lead, that is in cases where it is inconvenient to use two electrodes, such as for pin-point soldering and in awkward position.

"*The Hindu*".

27th November 1955.

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